WASHINGTON GEOLOGICAL SURVEY.

WASHINGTON

GEOLOGICAL SURVEY

HENRY LANDES, STATE GEOLOGIST

VOLUME II.

Annual Report for 1902

TACOMA:
PIONEER BINDERY AND PRINTING COMPANY
1903

BOARD OF GEOLOGICAL SURVEY.

HENRY MCBRIDE, - - - - - - - *President.*
Governor of Washington.

C. W. MAYNARD, - - - - - - - - *Secretary.*
Treasurer of Washington.

T. F. KANE, - - - - - . - - ———
Acting President of the University of Washington.

E. A. BRYAN, - - - - - - - - ———
President of the Washington Agricultural College and School of Science.

STAFF OF GEOLOGICAL SURVEY.

HENRY LANDES, - - - - - - - - - *State Geologist.*
Professor of Geology, University of Washington.

SOLON SHEDD, - - - - - - - - - - *Geologist.*
Professor of Geology, Washington Agricultural College and School of Science.

C. A. RUDDY, - - - - - - - - *Assistant Geologist.*

LETTER OF TRANSMITTAL.

To His Excellency, HENRY McBRIDE, *Governor of the State of Washington and President of the Board of Geological Survey:*

SIR—I have the honor to present herewith the Annual Report of the State Geological Survey for the year 1902. This report is in two parts, consisting of one paper on the Building and Ornamental Stones of the State, and another on the Coal Deposits of the State. It is hoped that these papers may mark the beginning of detailed reports upon various phases of the economic geology of Washington.

Very respectfully,

HENRY LANDES, State Geologist.

UNIVERSITY OF WASHINGTON,
Seattle, March, 1903.

CONTENTS.

PART I.

THE BUILDING AND ORNAMENTAL STONES OF WASHINGTON.

BY S. SHEDD.

PART II.

COAL DEPOSITS OF WASHINGTON.

BY HENRY LANDES AND C. A RUDDY.

ILLUSTRATIONS.

PLATES.

FIGURES.

PREFACE TO PART I.

The preparation of this report was begun in June, 1901, and since that time all of the localities, with perhaps two or three exceptions, where stone is being quarried for building purposes, or where it has been quarried in the past, have been visited and the deposits carefully studied. Samples of the various building and ornamental stones, represented in the various localities visited, were collected and a careful study made of these in the laboratory.

The time and funds at the disposal of the Survey have prevented the carrying out of certain things which would have increased very materially the value of this report. In a new state like Washington no first-class maps of the different parts of it are available, and as the Survey did not have the funds with which to make them it has not been possible to indicate the extent of the different building stone areas throughout the state. This would have been a very valuable addition, especially to that part of the report dealing with the marbles of Stevens County. Then, again, had the funds been sufficient to have some of the ornamental stones shown by means of colored lithographs, these would have added very materially to the value of the report.

There are many interesting scientific questions, also, in connection with the marbles and serpentines of Stevens County, which it has not been possible with the time at my disposal to do anything with, and they are necessarily left for some future time.

In the preparation of this report free use has been made of the various reports and publications on building stones, but of especial service have been Buckley's Report on the Building and Ornamental Stones of Wisconsin and Hopkins' Report on Marbles and Other Limestones. The chemical analyses given in this report (with the exception of the one of the serpentine from the property of the U. S. Marble Co., furnished by Mr. F. W. Clarke, Chief Chemist of the U. S. Geological Survey) were made by Mr. R. W. Thatcher, Assistant Chemist at the Washington Agricultural College and School of Science.

It has been thought advisable to include in this report a short chapter on quarrying and working stone; not that it is claimed that there is anything new in it, but because it was thought that it might be helpful to persons opening up quarries in Washington. I am indebted to the Sullivan Machinery Co., and The Ingersoll-Sergeant Drill Co., for illustrations of their stone quarrying machinery.

The tests of crushing strength, the results of which are given in this report, with two exceptions, and the modulus of elasticity were made at Purdue University, La Fayette, Indiana, and I am especially indebted to Professor W. F. M. Goss, Dean of the Schools of Engineering, and Mr. L. V. Ludy, of the department of Applied Mechanics, under whose supervision the work was done. I am also indebted to Mr. F. W. Clarke, of the U. S. Geological Survey, for his description and suggestions as regards the serpentine from the U. S. Marble quarry. To Professor J. P. Iddings, of Chicago University, I am also under obligations for microscopical descriptions of two tufas.

It is a pleasure to acknowledge my great indebtedness to the many quarry owners and superintendents, and others interested in the stone industry of Washington, who gave freely of their time and services, and without which the preparation of this report would have been almost impossible. To all others who have in any way aided in the preparation of this report I wish to express my hearty thanks.

S. SHEDD.

WASHINGTON AGRICULTURAL COLLEGE
AND SCHOOL OF SCIENCE.
Pullman, Washington, March, 1903.

PREFACE TO PART II.

In the report on the Coal Deposits of Washington an attempt is made to set forth in some detail the extent of our coal fields, the amount of development work which has been done within and upon them, and their commercial value. The small appropriation available for the report has necessarily limited the scope of the inquiry, and many important points have been omitted. An absence of reliable base maps has made it impossible to show with accuracy and in detail the boundaries of the various coal fields.

The field work upon which the report is based was done partly in the summer of 1901, but mainly in the summer of 1902. During these field seasons the following person were employed at various times as field assistants: L. D. Ryan, Charles Landes, S. H. Richardson and R. L. Ewing. The portion of the report which deals with the Packwood and Davis Fields has been prepared by Prof. Milnor Roberts.

The very kind assistance of the mine owners, managers and superintendents is gratefully acknowledged. Their friendly interest has been shown in many ways, and the information possessed by them has been cheerfully placed at our disposal.

HENRY LANDES.
C. A. RUDDY.

UNIVERSITY OF WASHINGTON.
Seattle, March, 1903.

PART I.

BUILDING AND ORNAMENTAL STONES OF WASHINGTON.

BY

S. SHEDD.

THE BUILDING AND ORNAMENTAL STONES OF WASHINGTON.

CHAPTER I.

ORNAMENTAL AND BUILDING STONES IN GENERAL

DEMAND AND USES.

Buildings—The demand for stone for building purposes is regulated by a number of different things, some of which are as follows: Cost of other kinds of material used for buildings; stability of stone as compared with other kinds of building material; "show" or the desire to give buildings as imposing an appearance as possible; the desire to make buildings more nearly fire proof, and the slowly increasing desire for more permanence.

The first thing, at the present time, when most people beging thinking about putting up a building of any kind is what it will cost and this causes them to begin to figure and compare the first cost of the different kinds of building materials that may be available, such as stone, iron and steel, brick and lumber, and usually the cheaper material is used. In this state the demand for stone for building purposes is not very great as yet on account of its first cost being much more than that of wood, brick or iron. And then again the people have not reached that stage of advancement where their ideas of permanence demand the stone, but rather they are simply building for the present, and leaving the future to take care of itself. The fact that Washington is well supplied with other material than stone for building purposes has tended to retard an increase in the demand for stone.

The demand, however, is slowly increasing and is much more now than it was ten years ago. An increase in the number of brick buildings being constructed usually calls for a larger amount of stone, as in nearly all cases stone is used

for foundations and trimmings, and in many cases the fronts will be built of stone and the sides and rear walls of bricks.

Stone is more stable than other kinds of building material and where the first cost is not the determining factor this question of stability enters as a factor to determine the kind of material to be used. In a new country like Washington the desire for large profits on small investments causes the rapid construction of buildings from cheap material, and the result is that a large part of our buildings are wooden structures. The desire on the part of most people to have as imposing looking buildings as their neighbors has in some cases caused a greater demand for stone, and many persons, who cannot afford to build stone buildings, veneer the fronts with stone so as to make them appear as imposing as many others built entirely of stone. This is true especially in regard to business blocks in the cities. In the cities the desire for fire proof buildings is constantly increasing and the wooden structures are gradually being replaced by structures in which the principal material is stone or brick. In some cases artificial stone, or material resembling stone, has been manufactured, and in so far as this has been used in buildings in just that far has it interefered with the demand for stone.

Monuments—Stone has been used for ages for monumental purposes, and there is hardly a cemetery in our land but what has its mausoleum of stone, and almost every lot its slab of marble. The demand for stone for monumental purposes is constantly increasing and better grades of stone are being used. It has been only a few years since it was very rare to find anything except marble used for monuments, but the demand for something more permanent has caused the marble to be partially replaced by granite. The marble is much more easily worked than granite, and hence cheaper, and this fact is a very strong point in its favor with a great many people. The demand for certain stones is determined quite largely by the reputation they have. This is due quite largely to the fact that the majority of the people are not capable of telling the difference between a good stone for monumental purposes and a poor one. Scotch granite has been used quite extensively

in this country, not because we do not have as good granites here, but principally because the Scotch granites had the reputation and our granites have had to make their reputations. The Scotch granites are gradually being replaced by our own native granites since we have found they are just as good and much cheaper on account of the tariff on the imported stone and the cost of transportation, which are expenses not met with in the case of the domestic stone. The atmospheric agencies affect the polished surfaces of the marbles and cause them to loose their polish much more quickly than the harder granites. Then the various colors found in the granite are more pleasing to most people, as a general rule, than the pure white of the marble. Our methods of cutting, polishing and working of the stone in general have been improved very much in the last few years, and this has caused the cheapening of stone so that people of moderate means can have a better grade of work done and use a better grade of material.

Road Making—Stone in some form has been used for road making to a greater or less degree since the time when roads were first built, but even at the present time the larger part of the stone used for road making is used by the cities and in the west especially very little is used by the country districts. A few years ago, stone in the form of blocks of granite, limestone and quartzite was used in many of the larger cities for street paving, especially on the streets subject to heavy traffic, but these are gradually being replaced by other forms of material such as vitrified brick, asphalt, and in some cases wooden blocks have been used. The wooden blocks, however, have not proven very satisfactory and are not now being used very much. Whether streets and roads are made of macadam, vitrified bricks, asphalt or wooden blocks a good foundation is a very important part of a good road or street and rock is the principal material used in the making of these foundations while asphalt or vitrified bricks are at the present time used as the surface material.

In road building or street paving the question of first cost is a very important factor in determining the material to be used. In Washington, outside of a few of the principal towns,

very little work of a permanent nature is done on the roads. It is true the roads are worked more or less each year, but the work done is not of a permanent character, and has to be done over each year and we have poor roads besides. Washington has very few miles of macadamized roads, not because the material needed for building such roads is not in the state, but because the people have not reached the point where they feel that it is better to concentrate their energies and build a few miles of good and permanent road instead of distributing their work over so large an area that nothing is well done and it all has to be done over the following season. Not all stone is suitable for road making material. A good road making material should be hard enough so that it will resist, wear well, and on the other hand it should not be so hard that it is slick and glassy. Then again it should have such a composition that the material when pulverized will cement together again and in this way it will form a solid, firm surface. If the material is so soft that it is abraded or worn away rapidly it will form volumes of dust during the dry season and quantities of mud during the wet season.

Curbing—The demand for stone, in the cities, for curbing has been increasing quite rapidly in the last few years until at the present time it is quite considerable. Even in our own state cities like Seattle, Tacoma and Spokane have in the last few years used quite a large amount of stone for this purpose.

Bridges and Culvert Construction.—There is a constant and growing demand for stone for bridges and culverts. In Washington, however, this demand is confined principally to the railroads and it has only been within the last few years that they have been using stone. When the railroads were first built through this state the bridges and culverts were all built principally of wood, but these are gradually being replaced by steel and stone structures. In many cases the railroads own and operate the quarries from which they obtain the most of their stone. The demand for stone for bridges and culverts on the public highways in this state is not very ex-

tensive as yet, but as the state becomes more thickly settled and we begin to build better roads the demand will gradually increase until eventually a large amount of stone will be used for this purpose and all of this will be supplied from private quarries.

Miscellaneous Uses.—In some places, especially in the large cities, there is quite a demand for flagging stone for sidewalks. Other uses such as retaining walls, jetties, steps, riprap, posts, etc., furnish a constantly increasing demand for stone. The stone that is probably used most for flagging is the sandstone, principally on account of the fact that it is stratified and is frequently capable of being split easily into thin slabs along the planes of stratification. Some of the Bellingham Bay stone from the Chuckanut quarries is quite good flagging stone.

NECESSARY CONSIDERATION IN THE SELECTION OF STONE.

Color.—The color of a stone, while, perhaps, not having very much to do with its real value, is frequently a very important factor in determining whether it will be used in certain places or not.

The color of many of our building stones is what has been designated a composite color; that is, it is a color made by the combination of two or more colors. The grayish color of so many of our granites is due to the fact that they are made up of white or light colored feldspar, and dark or black mica and hornblende finely divided and intimately mixed. In other cases the separate minerals occur in quite large particles and retain their separate colors and cause the mottled appearance so common in some granites. In other cases the feldspar is redish or pinkish and this is the cause of the red or pink granites which occur in some localities. The color of the sedimentary rocks is due principally to various forms of iron and carbonaceous matter. The limestones and marbles, when pure, are white and the reason they are so frequently colored is because they contain impurities of various kinds. The sedimentary deposits, such as the sandstones, vary a great

deal in color even in the same deposit, and frequently in short distances. When one understands the way these rocks have been formed this is what would naturally be expected. The material of which they are composed has been transported long distances by streams either in suspension or solution, and as the volume of water and kind of material would vary from time to time the color would probably change more or less. Then again percolating water may have changed the surface part of a deposit so as to give it an entirely different color from what it had at first and different from what the underlying rock still has. The cemeting materials in the sandstones are responsible to a considerable extent for their color. The common cementing materials in sandstones are calcium carbonate, silica and iron. When calcium or silica occur the stone is apt to be light colored and when iron occurs it is a buff or dark color, depending on the form in which the iron occurs. The color of stone is apt to change after it has been quarried and exposed to the atmosphere for some time. The principal cause of their first change is loss of water, but on further exposure a still greater change may take place, due to the chemical changes that are taking place in the constituents of the rock itself. If a stone contains iron in the form of a sulphide it will be changed by the action of the atmospheric agencies to an oxide and in this way change more or less the color of the stone. In some cases the color of a stone, regardless of its other qualities, determines, quite largely, its market value. The question of color is principally a matter of taste, and that being the case the demand for any particular kind of stone may vary on account of fashion.

Influence of Weathering.—Whenever rock has been exposed for some length of time to the different atmospheric agencies certain results or effects have been produced which are usually spoken of as weathering. This change may result in the breaking up completely of the rock and formation of soils, or it may result in only a partial decomposition or in the formation of new minerals as in the decomposition of a feldspar to produce a kaolin.

These weathering agencies may be separated into two classes depending on whether the action is principally a mechanical action or whether it is principally a chemical action. These two classes of agencies may be designated as those of mechanical disintegration and those of chemical decomposition.

The principal agencies of mechanical disintegration are (1) changes of temperature; (2) mechanical abrasion; (3) growing organisms. The principal agencies of chemical decomposition are (1) water-solvent action; (2) carbon dioxide; (3) organic acids.

Changes in temperature act in two different ways in producing decay of rock: (1) by unequal expansion and contraction of the rock or of the separate minerals of which it is composed; (2) by the expansion through freezing and the contraction, when thawed, of the water in the pores of the rock.

Agents of Mechanical Disintegration.

Unequal Expansion and Contraction.—It is a well known fact that in general substances when heated expand and contract unequally for the same variations in temperature. Rocks are poor conductors of heat and one side of a comparatively thin layer may be changed in temperature quite a good many degrees before affecting the other side. The igneous rocks are mixtures of several minerals, and each mineral has a different rate of expansion and contraction for the same changes in temperature. That is if the temperature of each mineral composing a piece of granite, for instance, be raised 10 degrees, the amount of expansion will be different for each one. Then again these minerals do not expand equally in all directions, but expand more in some directions than they do in others. The minerals in igneous rocks are more or less interlocked with each other and the fact that they expand differently in different directions produces a very unequal strain and this repeated time after time finally separates the particles and causes the breaking up of the rock. The sedimentary rocks are not so complex as a general rule as the igneous and hence

are not affected so much by these changes. Where the rocks are exposed to the direct rays of the sun during the day the temperature is increased and they expand, and at night they cool again and contract, and this process goes on day after day indefinitely, and eventually particles are completely separated from the main mass. These changes in temperature, of course, are only surface phenomena, but if the small particles loosened by this means are constantly being removed it gives this force a chance to keep continually acting and eventually large masses of rock are completely disintegrated. A good case showing the expansive force of heat is cited by Buckley in his "Building and Ornamental Stones of Wisconsin," where he states that "the expansive force of heat is well shown in many of the limestone quarries of Wisconsin, where beds from 5 to 6 inches in thickness are for the first time exposed to the heat of the summer's sun. These thin beds become heated throughout their entire thickness, and arch up on the floor of the quarry, generally breaking and completely destroying the stone."

Freezing and Thawing of Included Water.—All rocks are more or less porous and these pores, before the rock is quarried, always contain more or less water, and after being quarried for some time and exposed to the atmosphere, they lose this water. However, when rain storms occur they are apt to absorb more water and if the temperature falls below the freezing point when the stone is in this condition the water will be frozen. As is well known water on freezing expands and in expanding exerts a pressure or expansive force equal to about 150 tons to the square foot. It is plain to see that if the rock contains any very large amount of water and freezes the result will be the spreading apart or separating somewhat of the particles composing the stone. Then the water thaws and freezes again and so on indefinitely and the result is that particles are finally completely loosened and fall off. This effect is principally on the surface of the rock and is the cause of the scaling frequently seen in buildings that are built of certain kinds of stone. In addition to the pores, which occur in the rocks, there are the openings which occur

along the joint, bedding and foliation planes. Water falling on the surface of the ground and more or less of it sinking into it enters these cracks or crevices and while it will flow more readily along these than it does through the pores of the rock, still many times these will be filled and freeze while in that condition. As has already been stated, water when freezing exerts a very great expansive force and will tend to separate the rocks along these planes and when the ice melts the rocks do not come back to their original position, but retain the position they had when the water was frozen in them. Then these cracks are filled again and refrozen, and the seams opened a little farther and the same process repeated time after time finally produces a perceptible effect and tends to weaken the stone. This is especially true of sedimentary deposits such as sandstones, particularly where they have marked bedding planes.

Mechanical Abrasion.—Mechanical abrasion is a very prominent source of decay of rocks in nature. The streams with their loads of sediments are constantly abrading or wearing away their beds and, more or less, their banks also. In certain localities, especially in the arid regions, the wind is a very important abrasive agent. In these localities dust storms take the place of rain storms and the dust and sand carried by the wind act as graver's tools in cutting the rock with which it is brought in contact and in many instances cut the rocks into very fantastic shapes. In some parts of Washington the amount of abrasive work done by the wind is considerable. The effect, however, on buildings is not very great. In some instances rain is quite an important abrasive agent in wearing away the different kinds of rocks, but it has so little effect on buildings that it perhaps hardly deserves mention, but in some particular cases it may have some effect by breaking off very minute particles from the walls.

Minor Agencies.—Plants of various kinds and under certain conditions tend to cause the decay of the rock. Where the roots and rootlets penetrate the cracks and crevices in the rocks they act mechanically and chemically to cause decay. As the roots grow and expand they tend to separate the rock

masses and particles more and more until finally they separate them completely. In many instances the walls of buildings are allowed to become covered with ivy and other forms of clinging vines. These send their small roots into the crevices in the walls and they have a tendency to cause particles to be broken off from the walls. Then again they form good places for the collecting of dirt and foreign substances which hold the moisture and have a tendency to absorb any injurious gases which may be in the atmosphere. The stone will absorb more moisture because the plants will hold it and not allow the wall to dry so soon at it otherwise would, and the more moisture the wall contains the greater the effects due to freezing and thawing, so that while these plants may be ornamental they can hardly help but shorten the life of the building.

The methods used in quarrying and working stone very frequently are such as to hasten very much the decay of the stone. Stone that has been quarried by blasting is very apt to be shattered more or less and in this way weakened. The stone may not show the effects of the blasting when first quarried, but the cementing together of the particles has been partially overcome at least and besides this there have been a great many very minute cracks and seams formed, perhaps microscopic, which give a better chance for the water to penetrate the rock. Again stone that is hammer dressed will not be as long lived as stone that has been sawed for the reasons given above. It makes a material difference with some stone as to how it is worked as regards bedding planes and in regard to the way it is placed in the building with reference to the position it occupied in the quarry; that is whether in the building it is so placed that the bedding planes are vertical or horizontal as they were originally.

The position in which stone is placed in the walls, especially if it be stone that occurs in bedded deposits, will have considerable to do with determining the length of life of the stone. Water will penetrate the stone along the bedding planes much more readily if they are vertical than when they are horizontal and consequently the effects from the freezing and thawing would be much greater in the first instance than

in the latter. If stone is placed on edge and the water soaks into it and then freezes the tendency would be to produce scaling or breaking off of small particles from the surface or faces of the walls.

Agents of Chemical Decomposition.

Water-Solvent Action.—Pure water has very little effect as a solvent of the different kinds of rocks, but as a matter of fact we have very little, if any, absolutely pure water occuring in nature. Rain water, which is as pure as any found in nature, contains many gases, especially carbon dioxide, and when water containing this gas comes in contact with the different kinds of rocks it has a tendency to dissolve the minerals of which they are composed and produce decay. Water percolating through the crust of the earth slowly dissolves a certain amount of the rock with which it comes in contact, and, in the case of a limestone, sets free more carbon dioxide which in turn attacks the limestone, dissolving more of it, and in some instances, such as the Mammoth cave in Kentucky, large amounts of the country rock are taken into solution and removed by the water. Under ordinary atmospheric pressure and temperature water does not retain any very large amounts of the different gases, but when water sinks into the earth's crust the pressure is increased and in many cases the temperature is raised and these cause the water to be able to hold more of the different gases in solution, which would cause more rapid decay of the rock with which the water comes in contact. This is quite an important agency in the decay of many rocks, but is so slow in its action that it has very little effect on the length of life of stone in the walls of buildings.

Organic Acids.—In nature the organic acids play quite an important part in the decay of rocks. In nearly all localities there is more or less decaying vegetation and as the rain water falls and comes in contact with this decaying matter it absorbs the organic acids that have formed and in percolating through the crust of the earth comes in contact with the different rocks and tends to decompose them. It is very seldom, however, if at all, that these organic acids have any effect on the stone after it has been placed in the walls of buildings.

INHERENT QUALITIES OF STONE.

Mineralogical Composition.—The mineralogical composition of a stone is one of the very important factors in determining its durability, and other things being the same that rock in which those minerals occur that resist decomposition best will be the most stable and resist longest the different agencies that are constantly tending to decompose it.

In the igneous rocks the mineralogical composition, as a general thing, is more complex than it is in the sedimentary rocks and the more complex the composition becomes the greater the chance that some of the minerals will be easily decomposed. The common minerals occuring in the igneous rocks are quartz, feldspar, mica, pyroxene, and amphibole. Of these quartz is the most stable and in fact is hardly affected by atmospheric agencies at all, except, perhaps, those that act mechanically, such as changes of temperature and the freezing and thawing of included water, and as this mineral absorbs very little water this would have very little effect and hence those rocks that are composed quite largely of quartz as a general thing are apt to be more stable than those in which this mineral is absent. The feldspars are quite stable minerals, but they do not resist the decomposing agencies so well as quartz and when they do decompose they form new minerals such as kaolin which is of no value in helping the rock to resist decomposition. Mica is a very prominent mineral in many of the igneous rocks and when it occurs in finely divided particles resists weathering very well, but when it occurs in large masses, on account of the fact that it occurs in very thin layers, many seams are exposed which give favorable conditions for the action of the atmospheric agencies. The amphiboles and pyroxenes are the least stable of the common or prominent minerals occurring in the igneous rocks. Other things being equal, that rock is most durable which is composed of those minerals that are most durable and for that reason the granites and rocks of that family are among our most durable rocks. The essential minerals of the granites are quartz and feldspar, and as has already been explained, these are very stable minerals, especially the quartz.

Sometimes the accessory minerals, in a rock, become very important factors in determining the rate of weathering of the rock. One of the most common of these accessory minerals is perhaps iron sulphide or pyrite, and it is probably as injurious, when it does occur, as any of them. This mineral, when brought in contact with oxygen in the presence of moisture or water, oxidizes and forms iron sulphate which is easily taken into solution and either carried out of the rock completely or brought to the surface and deposited as iron oxide. In this way stone in the walls of buildings may be discolored even if they are not weakened very much by the decomposition and removal of the pyrite.

The sedimentary rocks are grains of igneous or sedimentary rocks that have been broken off from the parent mass by the action of the atmospheric agencies, and then recemented or hardened into rock again. The common cementing materials are silica, calcium and iron. The sandstones are fine or coarse grains of sand, having either a silicious, calcareous or ferruginous cement. The rate of decomposition of the sedimentary rocks is due partly to the original constituent minerals of which they are composed and the cementing material holding these particles together.

Buckley, in his report on "The Building and Ornamental Stones of Wisconsin," pages 37 and 38, has the following to say in regard to the cementing materials in the sedimentary rocks:

"The important cementing materials, in the order of their importance, are silica, calcium carbonate and iron oxide. A number of authors in text-books and reports on building stone have treated iron oxide as next in importance to silica as a cementing material. As will be shown, this is not true. Silica is the most important of the three cements. Calcium carbonate, although probably in itself less durable than iron oxide, is next to silica as a cement. Iron oxide, in itself, is more durable than calcium carbonate, but owing to the absence of other necessary qualities, it contributes least to the durability of a rock, and is therefore of least importance as a cement.

"The relative value of a cement depends primarily upon its adhesive and cohesive powers. It may be observed that, among the sedimentary rocks, in which the cements are equally abundant, sandstone, in which the cement is silica, and limestone or dolomite, free from any considerable admixture of quartz, are the strongest rocks. The silicious limestones, or calcareous sandstones, are of intermediate strength. The weakest are those in which the cement is simply iron oxide. The point which it is intended to emphasize in this connection is that a limestone, dolomite or sandstone is strongest, when the cement is of the same kind as the original constituents. The reason for this is apparently in the fact that the force that binds like substances is stronger than that which unites unlike substances. Whether weathering proceeds more rapidly through mechanical disintegration or through solution depends more or less upon the kind of cement. For example, a silicious limestone disintegrates more readily than a pure limestone, while solution may be more rapid in the case of pure limestone. The walls of buildings contain comparatively little water and the capacity to withstand mechanical disintegration is the more important quality. The essential thing is to have the particles composing a rock firmly bound together. The affinity between quartz and siliceous cement, between calcium carbonate and calcareous cement is stronger than that which exists between quartz and calcium carbonate. Further it is apparent that the adhesion between iron oxide and quartz or calcium carbonate is less than that between calcium carbonate and quartz. If the particles to be bound together were hematite instead of quartz or calcite, then under the principle that cohesion is stronger than adhesion, iron oxide would serve the purpose of a cement better than either silica or calcium carbonate.

"Calcium carbonate, as a cement or otherwise, is quite readily taken into solution by carbonated waters. The cleavage facilitates disintegration and the inherent softness of the mineral admits of easy abrasion. Silica, on the other hand, is very refractory, is dissolved only with great difficulty under ordinary conditions and being one of the hardest of minerals,

does not respond very readily to abrasion. Iron oxide is one of the harder minerals, is not readily acted upon by water, and has a medium capacity to withstand abrasion."

Some of the less important substances occurring in the sedimentary rocks are clay, pyrite and bituminous matter. These in some cases may have an injurious effect on the stone, but in most cases they do not occur in large enough quantities to cause any detrimental effects. The clay may occur disseminated throughout the stone or it may be segregated and occur in masses and in this case it would probably cause the stone to weather unevenly, while if it were finely disseminated all through the stone the tendency would be more to weaken it. Pyrite in the sedimentary rocks would have practically the same effect as it would in the igneous rocks and this has been already explained.

Texture.—The texture of a rock is determined by the size and arrangement of the particles of the mineral substances of which it is composed and is a very important factor as regards its durability. The size of the grains, the distance apart, and the manner of contact have much to do with the strength and durability of the stone. In some cases the particles composing the rock are held together by simple adhesion while in others, such as some of the sandstones, the grains are more firmly held together by some cementing material, and in still another class, such as the igneous rocks, their great strength and durability are due to an intricate interlocking of the constituent particles composing the rock. The size and shape of the particles of a rock are factors in determining the amount of pore space it can have. For instance, a rock in which the particles are of a uniform size and spherical in shape is capable of having the greatest amount of pore space. It does not follow, however, that such a rock will always have a large amount of pore space as a part may have been filled by material being deposited around the grains.

The size of the pores in a rock may vary from those that are very minute and microscopic to those that are of considerable size and easily seen with the naked eye. The effects of a high per cent. of pore space in a rock are to cause it to have

a high ratio of absorption and also weaken it more or less, as other things being equal the less the amount of pore space the stronger the rock. Some rocks have substances scattered through them which weather faster than the main mass of the rock and in this way quite large cavities are sometimes formed and when these are formed in any very great numbers they are very injurious to the stone. The size of these cavities will depend on the size of the individual mineral particles and in many cases they will be so small that they will not be visible to the naked eye but at the same time they may be very injurious on account of their great abundance.

The sedimentary rocks are apt to vary more as regards the size and composition as well as the compactness of the grains than the igneous rocks. In many instances these variations are plainly noticeable in single beds while in other cases it is seen only in different beds. In the sedimentary rocks, such as sandstones and many limestones, such as those containing a large number of fossils, the cementing material does not resist weathering as well as the rest of the stone, and hence it is worn away faster and the surface becomes very rough and uneven.

Hardness.—The hardness of a rock is determined by the hardness of the minerals composing it, the size of the component mineral particles, and the state of their aggregation. A rock may consist of grains of the hardest of minerals and still be very soft, this being due to the fact that the grains are not firmly cemented together, while on the other hand the individual grains might be quite soft but well cemented together and the rock still be fairly hard, so that it is very plain that the way in which the individual grains are bound together is very important factor in determining the hardness of any rock. Of two rocks in which the conditions as regards the size and shape of the grains and cementing material are similar, the one in which the individual minerals are the hardest will be the harder rock. A knowledge of the mineralogical composition aids us in forming an idea of its hardness and comparing it with other rocks. Not all rocks, however, having the same mineralogical composition are of the same

hardness, owing to the variation in the per cent. of the different minerals found in them. In the sedimentary rocks the shape of the grains has much to do with the hardness of the rock and other conditions being similar that rock in which the grains are irregular in outline and having sharp corners and interlocking, something after the fashion of the particles in the igneous rocks, will be the hardest. In some sedimentary rocks the cementing material is harder than it is in others and this has an influence on the hardness of the rock mass.

CHAPTER II.

LABORATORY TESTS ON BUILDING AND ORNAMENTAL STONES.

In all laboratory tests that are physical tests the conditions under which they are made are not the conditions under which the stone will be when it is placed in the walls of buildings. The laboratory tests are as a general thing made under very extreme conditions. A series, however, of well planned and carefully conducted physical tests of any particular building stone is in many cases of very great value. The knowledge gained by such a series of tests will enable a person, if he knows the conditions under which the stone is to be placed, to predict with a fair degree of accuracy, without an examination of the quarry, the results of exposure to the atmospheric agencies.

So important are these tests that in the case of new quarries or of stone that is being placed on the market for the first time, owners should not expect any very great sale until the tests have been made and the quality of the stone proven, as far as it can be by this means. Before any very large amount of money is spent in opening up a new quarry the stone should be carefully tested in the laboratory and its character determined. In many cases stone is put into buildings without these tests having been made and as a result in a few years when the buildings begin to decay and look shabby the owners realize the value it would have been to have had the stone tested before using it. Instances of this kind are found in Washington where stone has been used in buildings and after a very few years of exposure to the atmosphere it has commenced to crumble and decay. A careful testing of the stone would have shown the unfitness of it for building purposes and in the end would have saved much expense.

In the preparation of this report the laboratory tests have been considered under the following heads::

1. Microscopical; 2. Chemical; 3. Physical.

MICROSCOPICAL TESTS.

In the study of rocks a good hand lens is very useful and in the case of most rocks much may be learned, as regards structure and mineralogical composition, by a study of hand samples, in this way. Many rocks, however, are of such a character that to determine accurately the structure and mineralogical composition the compound microscope is needed. For use with the microscope thin slices of the rock to be examined are cut and ground down so thin that light will pass through them and then mounted on an object glass for inspection.

The microscopical examination is a very important one but only within the last few years has it been very extensively applied. One of the most important things to know in considering the value of a building stone, is its mineralogical composition. This is apparent when we stop and consider the fact that the same elements might be present in two different rocks and united in different ways in each case and thus forming different minerals. In one case minerals might be formed that would resist weathering well, while in the other case the minerals formed might be easily decomposed. With the microscope and thin sections the mineralogical composition of a rock can be told.

Another very important factor in determining the value of a stone for building purposes is the size, shape and way in which the individual grains or particles are united and the only way in many cases at least that this can be told is by the aid of the microscope. Impurities may be detected that would not be found in any other way. The condition of the grains composing the rock, that is as to whether they are perfectly fresh or partially decomposed, can in many cases be told only by the aid of the microscope and thin sections.

CHEMICAL TESTS.

The chemical analysis of a rock will show what elements are present and in what proportions, but it does not show in what combinations they occur. The presence and amount of any substances which are harmful may be ascertained. The presence of iron and the condition in which it occurs, i. e., whether it is ferrous or ferric iron can be told by chemical analysis. The presence of magnesium carbonate in a limestone or marble can be told by a chemical analysis but could not be recognized by a microscopical examination. Chemical analyses have been much more generally made than the microscopical examination on account of the fact that the means for making the chemical analyses are more accessible than the other. Both the chemical analysis and the microscopic examination are very valuable and in many cases neither can be dispensed with if we are to have anything like a fair knowledge of the stone and in the preparation of this report both have been used.

PHYSICAL TESTS.

Physical tests of building stones are the tests that are made to determine artificially the strength and ability of the stone to resist the natural weathering agencies or destructive forces encountered in actual use. In Washington the buildings are comparatively new and the stone quarried in this state has not been in use long enough so that it is possible to say, from actual experience, as to whether it is durable or not. The strength of a stone may be easily tested but the strength is not the only thing to be taken into consideration in estimating the durability of the stone.

The trouble with all the physical tests is the difficulty of making the tests under exactly similar conditions to those under which the stone is placed in actual use. In the artificial tests the conditions are extreme but constant all the time while in actual use they are continually changing. Then again in the artificial tests there is usually but a single force acting at one time, while in nature, as a general thing, there are several acting at the same time.

Buckley* separates the physical tests into two classes as follows:

A. Strength Tests.

1. Crushing strength.
2. Traverse strength. Modulus of rupture.
3. Modulus of coefficient of elasticity.

B. Durability Tests.

1. Specific gravity.
2. Porosity.
3. Weight of the stone per cubic foot.
4. Effect of extreme heat.
5. Effect of alternate freezing and thawing.
6. Action of carbonic acid gas.
7. Action of sulphurous acid fumes.

A. Strength Tests.

Crushing Strength.—Until recently about the only test that had been used in determining the suitability of a stone for any particular use was the crushing or compressive strength test and by many quarrymen and builders it has been considered that this test is all that is needed to determine the quality of any stone. The value of this test, however, has been in many cases very much overestimated. It is a rule among builders that a stone should never be placed where it will be subjected to more than one-tenth the pressure that the fresh sample has shown by actual experiment that it can resist.

Buckley † in speaking of the value of this test has the following to say:

"It has been computed that the stone at the base of the Washington monument, the highest structure in the world, sustains a maximum pressure of 22,658 tons per square foot, or 314.6 pounds per square inch. Certain contractors require a stone to withstand twenty times the pressure to which it will be subjected in the wall, while others only require ten times that pressure. Even if requiring a factor of safety of twenty, the strength required for a stone at the base of this monu-

* Building and Ornamental Stones of Wisconsin, p. 57.

† Building and Ornamental Stones of Wisconsin, p. 58.

ment would be only 6,292 lbs. per square inch. The pressure at the base of our tallest building can scarcely exceed one-half that at the base of the monument, or 157.3 lbs. per square inch. According to the above estimate stone used in the tallest buildings does not require a compressive strength above 3146 lbs. per square inch. There is scarcely a building stone of importance in the country that does not give a higher test than this. Ordinary building stone has from two to ten times the maximum required crushing strength. A stone, having a crushing strength of 5,000 lbs. per square inch, is sufficiently strong for any ordinary building."

From the above it would seem that there are very few stones that, when fresh, would not have great enough crushing strength so that they would be able to resist the pressure to which they would be subjected when placed in buildings. The question of long continued pressure and what the result would be and how much the stone will be weakened by this and long exposure in the walls of buildings is one that cannot be answered very definitely at the present time. We know that a stone that has been subjected to great pressure and has this pressure removed will not stand the same maximum strain when placed under pressure again.

In making tests of the crushing strength of any stone the results depend very materially on the way in which, and the care with which the samples have been prepared, and before it is possible to draw conclusion from tables showing the crushing strength of building stones it is necessary to know the way in which the samples have been prepared and the condition of the samples at the time the tests were made. Cubes that are prepared with a hammer or chisel are often shattered more or less, seams are frequently produced, and grains loosened, all of which tend to weaken the stone and cubes that are prepared by sawing or rubbing will usually be much stronger than those prepared with a hammer or chisel.

Most of the cubes used for crushing tests in the preparation of this report were approximately two inches. A few were a little less. In some instances the cubes were prepared by the quarry owners and in others they were prepared in

the laboratory of the Washington Agricultural College and School of Science, and in most cases they were sawed and rubbed. The cubes were cut from blocks which so far as could be told were free from flaws and the faces rubbed down until they were approximately parallel. The cubes were then allowed to thoroughly dry, after which they were sent to Purdue University, La Fayette, Indiana, where they were tested.

The following description of the method of making these tests was furnished by Mr. L. V. Ludy, in charge of the department of Applied Mechanics, Purdue University, under whose supervision the work was done:

"The tests were made in a vertical testing machine in the usual way, by placing the specimen between the head and base of the machine and applying load until failure occurred. The forms of the specimens were cubes of approximately two-inch edges. In order to obtain a perfect bearing on the specimen, plaster of paris was used, with sized paper between the specimen and plaster to prevent the moisture from affecting the physical qualities of the specimen.

It was desired in these tests to obtain the ultimate strength and modulus of elasticity. In order to accomplish the latter it is necessary to know the relation between the compression of the stone and the load required to produce this compression. To gain this information two yokes were designed which were placed around the specimen, one at the top and one at the bottom, and clamped in position by means of thumb-screws with rounded ends. By this arrangement the actual amount of compression of the stone between thumb-screws in yokes could be measured. The amount of this compression was measured by means of a compressometer which read to the one-ten-thousanth part of an inch. The average length of stone, in which the compression was read, was about one and one-eighth inches, and represents the distance between thumb-screws in yokes.

The stone being in position in the machine, loads were applied, increasing uniformly and corresponding readings of the compressometer were taken. By very careful measure-

ments of the apparatus it was found that the calculated results could be relied upon as being correct to within one or two per cent."

B. Durability Tests.

Specific Gravity.—The specific gravity of a stone is found by comparing its weight with the weight of an equal volume of water. Several different methods have been employed by different persons for doing this and in many cases the results are not entirely correct. Gen. Gilmore weighed the stone first in air, then suspended it in water and when bubbles were no longer given off he weighed it in water. Then it was taken out of the water, the surplus water removed from the surface of the sample by means of blotting paper or some other good absorbent and weighed in air again. Then the difference between this last weight in air and the weight in water divided by the weight in air of the dry stone was taken to be the specific gravity of the stone.

At the Rose Polytechnic Institute, Terre Haute, Indiana, the samples are weighed in air and then immersed in water and weighed as quickly as possible. The difference between these two weights divided by the weight in air gives the specific gravity. Each of these methods as shown by Buckley* are faulty. The true dry weight in many cases, and perhaps in all, is not obtained, as it is necessary in order to expel all the water to heat the stone to 110° C. for some time. Then again the weight in water is faulty, as the correct weight is not obtained until the sample is completely saturated and this even under the most favorable conditions takes quite a considerable length of time and is not completed when bubbles cease to be given off. "A third method is that which is commonly known as the specific gravity bottle. By this method a small bottle is weighed, filled with distilled water and weighed again. The bottle is them emptied, dried, the powdered stone put in, and reweighed. These weights give the weight of the stone and the weight of the bottle full of water. The bottle containing the sample is partly filled with

* Building and Ornamental Stones of Wisconsin, pp. 63 and 64.

water and suction applied to exhaust the air bubbles, the filling completed and another weight taken. The specific gravity is then computed by dividing the weight of the stone by the weight of the water displaced by the stone."* If sufficient care is exercised in the manipulation this method should give very good results.

The determinations made in the laboratory of the Washington Agricultural College and School of Science in the preparation of this report, were obtained by the method used by Buckley in the preparation of his report on the Building and Ornamental Stones of Wisconsin.

The samples used for the determination of specific gravity, with a very few exceptions, were approximately one inch cubes. These were dried in a hot air bath at a temperature of 110° C., until a constant weight was obtained. The weight was recorded in grams to the third decimal place. After this the samples were placed in a large bottle and the cork tightly sealed. It was then placed in a water bath, containing water, and at a temperature of 100° C., which was maintained throughout the forty-eight hours that the samples were in the bottle. The bottle was connected with an air pump and the air exhausted until the pressure in the bottle was reduced to at least an eighth of an atmosphere. Water which had been boiled and had a temperature of 100° C. was slowly fed into the bottle, the air pump being worked at the same time, and in this way the pressure in the bottle was kept constant or nearly so. The water was fed into the bottle by placing one end of a rubber tube in the basin of hot water, the other end being attached to a piece of glass tubing which passes through the cork into the bottle. By means of a pinch cock the rate of flow of the water into the bottle was easily regulated. The water was fed into the bottle slowly until the samples were entirely covered.

The samples were allowed to remain in the bottle 48 hours, then removed, placed in a pan of distilled water and taken and weighed. Before weighing the water was removed from the surface of each sample by means of blotting paper, then

* Building and Ornamental Stones of Wisconsin, p. 64.

placed on the scale pan and weighed as quickly as possible. In order to ascertain if the samples were completely saturated they were placed in the bottle again under the same conditions as before and allowed to remain for 12 hours more, when they were again weighed and in some few cases a very slight increase in weight had occurred, but not enough to make any very perceptible difference in the results. The samples while still saturated were suspended, by means of a fine wire, in distilled water and again weighed. The specific gravity was then determined by dividing the dry weight by the difference between the dry weight and the weight of the sample suspended in water. The results are recorded in Table II.

Porosity.—The percentage of pore space in a rock is usually determined by dividing the difference between the dry and saturated samples by the weight of the dry sample. Buckley* in discussing porosity objects to this method and says it does not give the pore space but rather a result that would better be called ratio of absorption. In order to show as low a percentage of pore space as possible methods that are not strictly correct are sometimes used.

The results shown in Table II. of this report were obtained as follows:

The dry and saturated weights used in the determination of the specific gravity were used. The specific gravity was multiplied by the difference between the dry and saturated weights and the product added to the dry weight. This product was then divided by the sum of the dry weight and the product and the result taken as the percentage of pore space as compared with the volume of the sample tested. This is the method used by Buckley in the preparation of his report on the Building and Ornamental Stone of Wisconsin.

Weight of Stone.—The weight of stone when it is taken out of the quarry depends principally upon the specific gravity of the stone, the amount of water it has, and the amount of pore space. For any given rock the amount of water is the variable quantity. Any determination of the weight of a

* Building and Ornamental Stones of Wisconsin, pp. 68 and 69.

given stone to be of value should be made on the dry stone and not on samples which contain indefinite amounts of water.

The results given in this report were obtained by multiplying the weight of a cubic foot of water by the specific gravity of the stone which gives the weight of a cubic foot of the stone if it were free from pores. This result was multiplied by the per cent. of pore space already found and the product subtracted from the result obtained by multiplying the specific gravity of the stone and the weight of a cubic foot of water together and the result is the actual weight of a cubic foot of the stone. The weight per cubic foot of the stone from the quarries of Washington is given in Table II.

Freezing and Thawing.—The freezing and thawing test is an important one and especially if the stone is to be used in a wet, cold climate. As has already been stated the water been brought to Lewiston on scows and then reloaded and in the pores of the rock expands when it freezes and this tends to produce disintegration of the rock. The effect of freezing and thawing can be determined with a greater degree of accuracy in the laboratory than any other place. This is due to the fact that here we have the one force acting, while in nature there are a number of disintegrating forces acting together. Two methods have been used in determining the effect of alternate freezing and thawing and they are known as the natural and the artificial methods. The artificial method consists in boiling the samples in a solution of some soluble salt, such as sodium sulphate, until they are saturated and then allow them to dry. As the water evaporates the salt crystallizes and produces stresses similar to those produced when the water freezes in the pores. The conditions, however, were such that in the tests made for this report the samples could be saturated with water and frozen at night so that nothing was done with the artificial method.

For making the freezing tests on the stone from the Washington quarries, the results of which are recorded in this report, approximately inch cubes were used with two or three exceptions. The samples were dried in a hot air bath at 110° C. to a constant weight and the weight recorded. They

were then saturated with water and at night placed out of doors and allowed to freeze. In the morning they were brought into the laboratory, allowed to thaw out, then placed in distilled water and left to soak until evening, when they were again placed out of doors and allowed to freeze during the night. This was repeated twenty times, after which the samples were again dried in the hot air bath at 110° C., and reweighed and the loss of weight computed. Probably the most important test in connection with freezing and thawing is the determination of the effect on the strength of the stone, but unfortunately in the preparation of this report it was not possible to make tests to determine this.

Extreme Heat.—The ability of a building stone to withstand extreme heat, in many cases at least, is a very important one. This is especially true in the case of material which is to be used in cities where it is liable to be subjected to the intense heat of the conflagrations from which many of our cities have suffered and are liable to suffer at any time. Different kinds of building materials vary much as regards their power to withstand high temperatures, but at the same time they may all be destroyed if the temperature is high enough. Some are even destroyed at quite low temperatures while others are but little affected at from 1100° F. to 1300° F. Stone is a poor conductor of heat and in the case of a fire in the cities the stone becomes heated to a high temperature on the outside and then, frequently at least, is cooled very suddenly. This sudden cooling causes the outer part to contract suddenly and the stresses thus caused produce fractures in the outer part of the rock and particles and sometimes large masses are thrown off. This repeated for a number of times may completely destroy the rock. Other things being equal the stone that has the simplest mineralogical composition and the most uniform texture will have the greatest capacity to withstand high temperatures and sudden changes.

The temperature tests made in the preparation of this report were performed by placing samples, mostly inch cubes, in a muffle furnace and gradually bringing the temperature to 800° F., after which they were removed from the furnace

and some of them cooled suddenly by being put into cold water and others were allowed to cool slowly. Specimens were then placed in the furnace and the temperature increased to 1200° F., after which they were removed from the furnace and allowed to cool. Samples of the stones that were not destroyed at 1200° F., were placed in the furnace and raised to a temperature of 1600° F., after which they were allowed to cool gradually.

Carbonic Acid Gas.—The limestones and marbles are the only rocks that are affected to any extent by the action of this gas, which is manifest mainly in the large cities where large amounts of soft or bituminous coal is used. Tests were made in the laboratory on the marble and dolomites of Stevens county, to determine what the effect of this gas would be on these stones. The tests were made on samples which were cubes, the edges of which were approximately one inch long. These samples were first dried at 110° C. to a constant weight, after which they were placed in wide-mouth bottles, in which there was a small bottle containing water, and the corks carefully sealed. The bottles were then connected with CO_2 generators by means of glass and rubber tubing. Carbon dioxide was then passed into the bottle until it was filled and then the tubing was closed to prevent the escape of the CO_2, by means of pinch-cocks. The carbon dioxide was renewed three times a week through a period of twenty days. The samples were then removed, washed in distilled water, dried at 110° C., and weighed. The difference of weight is recorded in Table IV. The samples showed no evidence of deterioration.

CHAPTER III.

GRANITE, TUFA AND BASALT OF WASHINGTON.

GRANITE.

Distribution.—Granite suitable for building purposes is found in a number of places in Washington but at the present time the demand is not sufficient to warrant the working of many quarries. In time the demand will probably be much greater and new quarries will then be opened.

In Western Washington the principal locality where quarrying has been done is at Index and two quarries have been opened at this place. Granite occurs in a number of other places in Western Washington along the line of the Great Northern Railway. It also occurs near Granite Falls and North Bend and probably at many other places not mentioned. Russell* mentions it as occurring along the Sauk river, the Skagit river from near Marblemount up stream a distance of about 20 miles, and a small area south of Monte Cristo.

In Eastern Washington granite has been quarried at a number of places and is known to occur in many others. Granites are quite common in Kittitas, Chelan, Okanogan, Ferry and Stevens counties but in none of these has it been quarried to any extent. In Spokane and Whitman counties quarries have been opened and considerable granite taken out. Through Southeastern Washington the country rock is basalt and only in a few places comparatively do other kinds of rock occur, the principal ones of which, so far as granite is concerned, are near Medical Lake, near Spokane, on the Little Spokane river, and at Granite Point on the Snake river.

The surface of the country through Southeastern Washington before it was covered over with the basalt was very rough and irregular and in fact mountainous, the mountains being composed of entirely different kinds of rocks from those

* 20th Annual Report U. S. G. S., Part II., p. 107.

SNAKE RIVER GRANITE QUARRY, NEAR WAWAWAI.

CUSTOM HOUSE, PORTLAND, BUILT CHIEFLY OF SNAKE RIVER GRANITE.

found on the surface at the present time, or basalt. This is shown by the outcrops of metamorphic and igneous rocks such as gneisses, quartzites, granites and schists, which occur at various places throughout the basaltic area. Several splendid illustrations of the outcropping of these rocks, which composed this older land surface, are found within a short distance of Pullman. One of the best of these illustrations is Steptoe Butte, which is about twenty-five miles north and a little west from Pullman. This butte is principally quartzite and rises about 1,000 feet above the surrounding country. It is almost conical in shape and stands out as an island in the basaltic area. North of Pullman ten miles is Kamiack Butte and while it does not rise so high above the surrounding country, still it goes to help prove the very uneven character of the surface of the country before the basaltic overflow. Kamiack is composed mainly of quartzite and rises 500 feet above the surrounding country. Both of these buttes existed as, perhaps, quite high mountain peaks before the basaltic overflow and were not completely inundated by it. Other outcrops of metamorphic rocks of less extent are found within a short distance of Pullman.

Near Rosalia gneisses and quartzites are found outcropping through the basalt. At what is known as the "hole in the ground," near Rock Lake, an outcrop of what appears to be quartz schist occurs. At Granite Point on Snake river granite rises 150 feet above the water and this is 3,500 feet below the top of Steptoe Butte. This would tend to show that Steptoe must have been quite a prominent peak even before the time of the basaltic overflow.

There are no indications found where the basalt rests on these older rocks that they have been pushed up through the basalt. Professor I. C. Russell * in discussing this point gives the following:

"About 15 miles up the Snake river from the town of Asotin is a locality known as Buffalo Rock, which is of especial geological interest. This locality can be reached conveniently

* Water Supply and Irrigation Paper No. 4, U. S. G. S., p 31.

from Asotin by following a road recently opened along the west side of the river and at the bases of the great precipices of basalt that form the canyon walls. Above Asotin the canyon of the Snake river is deeper than below that locality and furnishes many striking exposures of columnar basalt, which rise tier on tier to a height of over 3,000 feet. In the neighborhood of Buffalo Rock, however, an important change occurs. The metamorphic rocks which formed the surface of the country before the vast inundation of molten lava took place again appear above the level of Snake river and rise at least 2,000 feet into the horizontally bedded basalt. The river has cut its gorge across a buried mountain so as to expose the rocks composing it for about a mile on each side of the stream. The horizontal layers of basalt abut against the steep sides of the old mountain and show no evidence of disturbance at the contact. It is evident that the lower rocks have not been forced up into the basalt but that the latter was poured out in successive sheets and flowed about a mountain of schist and finally overtopped its summit and buried it from sight. Additional overflows of the same character were spread over the site of the buried mountain and reached a thickness of fully 1,000 to 1,500 feet above its summit before Snake river began to excavate its canyon.

The sides of the buried mountain, where they first appear above the river, are steep and without talus slopes or other products of disintegration. Although 3,000 feet of horizontally bedded basalt are exposed in the canyon walls adjacent to the outcrops of schists, it is evident that the valleys of the old land lie below the level to which Snake river has corraded its channel."

Snake River Area.

Snake River Granite Quarry.—This quarry, owned by Mr. Miles C. Moore, of Walla Walla, is located about two miles above the mouth of Wawawai canyon, on the bottom of the Snake river canyon. It is in Sections 13 and 24, T. 13 N., R. 43 E., and is 30 miles down the river from Lewiston. The Oregon Railway & Navigation Company at present operates a

line of boats from Riparia to Lewiston and the same company is now building a line of railroad from Lewiston to connect with their main line at Riparia which will pass by the quarry and give a better means of shipping the stone than has existed heretofore when it had to be loaded onto scows and towed to Riparia and then rehandled and loaded onto cars.

The granite at this place is a ridge that was completely covered with the basalt and has been exposed by the Snake river cutting its channel deep enough to get through the basalt which covered the granite. The granite is exposed for about one-third of a mile along the river and in the highest places rises something like one hundred and fifty feet above the water. The canyon walls are composed of the edges of horizontal layers of basalt which rise 1,800 feet above the top of the ridge of granite. This basalt shows the least depth to which the granite was buried by the basaltic overflows. I say least depth because we do not know what thickness of overlying basalt has been removed by the atmospheric agencies. Considerable stone has been quarried and shipped from here to different places where it has been used for building purposes, street curbing, and bridge piers. Fifty thousand cubic feet of this stone were used in the new government building in Portland, Oregon.

The Snake river granite is a light gray biotite granite with very little hornblende present. The mica occurs in layers, to a certain extent, giving to the stone somewhat the appearance of a gneiss. The stone along the seams where the water has circulated for years is somewhat colored by iron, which is due partly to the decomposition of the iron bearing minerals in the granite and partly to the iron being brought from the decomposing basalt which covered and surrounds it even at the present time. The joints and seams are not frequent enough but what blocks large enough for all ordinary purposes may be obtained. The stone is firm, resists weathering well, and is a good building stone. It works nicely and is said to take a very high polish. This quarry has been worked entirely by hand, the stone being broken down with powder and then worked into dimensions by splitting with plug and feather.

The quarry is not operated continuously but only as orders are received. At the present time (Sept. 1902) no stone is being quarried at this place.

Mr. Moore also has another granite quarry further up the Snake river near the mouth of the Grand Ronde river. The stone here is darker colored and finer grained than the stone from the other quarry. This stone is said to take a very fine polish and has been used to some extent for monumental purposes. This quarry, however, is not very easily accessible on account of the fact that the Snake river is practically unnavigable above Asotin. At times of high water, however, boats have been above the quarry and some of the stone has shipped from there.

Under the microscope thin sections of this granite show it to be composed principally of quartz, feldspar and mica. The feldspar is more abundant than the quartz and both the orthoclase and plagioclase are present. The individual grains composing this rock vary much in size and range from those that are not more than a millimeter in diameter up to those that are as much as one-fourth of an inch in diameter—these being the feldspars.

In ordinary light the quartz is almost transparent but in the sections examined it is not very common at least not so common as the feldspar. The feldspar has a clouded appearance but does not show the zonal structure which is so frequently found in this mineral. The decomposition has taken place along the minute seams which are very common in the feldspars in this granite. In places the sections show places where they have the appearance of being a collection of crushed mineral fragments. The mica occurs in flakes and masses of varying size and in the hand specimens occurs more or less in layers and gives them a somewhat banded appearance.

In polarized light between crossed nicols the polysynthetic twinning so characteristic of plagioclase is well shown. In some cases inclusions are quite noticeable and these vary considerably in size but in no instance are they very large.

The following chemical analysis shows the composition of the granite from this locality:

Silica ($Si\ O_2$)	71.70
Ferric iron ($Fe_2\ O_3$)	1.46
Ferrous iron ($Fe\ O$)	1.80
Alumina ($Al_2\ O_3$)	14.54
Lime ($Ca\ O$)	3.13
Magnesia ($Mg\ O$)	0.39
Water at 100° C. ($H_2\ O$)	....
Water above 110° C. ($H_2\ O$)	0.92
Alkalies and undetermined	6.06
	100.00

In the above analysis, the alkalies not having been separated, it does not show the kinds of feldspars that are present nor in what proportions.

In making the physical tests two inch cubes of this granite were prepared by cutting them by hand with hammer and chisel to approximate size, and then rubbing the faces smooth. These cubes were used in making tests of the crushing strength of this stone, and as shown in Table I. it ranges from 10,730 to 16,400 pounds per square inch, while the modulus of elasticity is from 1,532,000 to 5,135,000 pounds to the square inch. While these tests do not give a very high crushing strength for this granite, at the same time it is probably great enough for all practical purposes and in fact far in excess of the pressure to which it will ever be subjected in any building or structure of any kind.

Reference to Table II. shows the specific gravity to be 2.677, the ratio of absorption as shown in the same table is .36 of 1 per cent, and the percentage of pore space is .969 of 1 per cent of the total mass of the rock. The samples used to determine the specific gravity and the porosity were alternately frozen and thawed each day, for a period of twenty days, and the loss in weight carefully determined. It will be seen by referring to Table III., that the loss in weight of a cube weighing 114.417 grams was .043 grams, or .036 of 1 per cent of total mass of the rock. The crushing strength of the frozen sample was not tested to see how much the stone had been weakened.

Samples were heated in the muffle to test the power of

this granite to resist high temperatures and sudden changes. At a temperature of 800° F., the stone crumbled on the edges and when heated to 1,200° F., and cooled the sample emitted the peculiar ring characteristic of stone which has been heated to a red heat and the strength of the rock was practically gone. A sample was heated to 800° F., and cooled suddenly by being plunged into cold water, the result being that the strength of the sample was almost entirely destroyed it being so weak that it could be powdered between the fingers. The feldspar was somewhat changed in color, the slightly pinkish tinge which is found in some cases being considerably intensified.

Index Area.

Soderberg Quarry.—This quarry is on the main line of the Great Northern Railway, about seventy-five miles from Seattle, and is in Sec. 19, T. 27 N., R. 10 E. The quarry is about one-half mile below the town of Index, and is along the side of the railway. A short side-track has been built to facilitate the loading of the stone on the cars. The granite quarried at Index is used almost exclusively, wherever granite is used, throughout the Sound region, except for the finer grades of monumental work, and large quantities of it have been used for street curbing, foundations for buildings, and various other purposes.

The Index granite is a light colored, medium grained, biotite-bearing hornblende granite. It appears to work quite easily, for a granite, splitting very straight and regular. The granite is broken down by blasting and then worked into sizes and shapes as desired. The quarry is operated entirely by hand with the exception of a steam hoist and derricks for handling the large blocks. The supply of granite here is practically unlimited as the mountains in this locality are practically all composed of granite. This stone is well suited for building purposes and all kinds of rough work, but does not take a good polish. The quarry is not operated continuously but just to fill orders as received. During the summer of 1901 a force of thirty men was employed in getting

out curbing for the Seattle streets. This granite appears to resist weathering quite well as it is only affected very slowly by atmospheric agencies, and blocks that have been exposed to these agencies for years show very little change in color. Along the seams in the quarry some discoloration is found, due to the decomposition of the hornblende and the freeing of the iron, but this is on the surface only.

An examination of thin sections under the microscope of the granite from this locality shows the rock to be composed principally of quartz, feldspar and hornblende, with a little biotite. The grains are of medium and fairly uniform size. Feldspar is the most abundant constituent, composing from two-thirds to three-fourths at least of the entire rock. The hornblende is much more abundant than the biotite, and the rock would be designated as a hornblende-biotite granite. The feldspar is almost pure white with occasionally a very slight pinkish tinge which is not marked enough to have any influence on the color of the rock. The color of this rock is a light gray produced by a blending of the light colored feldspar and the black hornblende. As seen in ordinary light the feldspar has a dirty appearance and the individuals are considerably granulated about their edges. Twinning of the feldspars is common. The feldspars are orthoclase and plagioclase with a preponderance of the latter. The minerals all have very irregular outlines and interlock in an intricate manner. Many of the feldspars show very plainly the zonal structure, due probably to weathering, while others again show transverse markings, which are due to weathering along transverse seams in the crystals.

The following chemical analysis of a sample from the Soderberg quarry shows the composition of this granite:

Silica ($Si\ O_2$)	67.45
Iron ($Fe_2\ O_3$)	8.34
Alumina ($Al_2\ O_3$)	13.04
Lime ($Ca\ O$)	4.68
Magnesia ($Mg\ O$)	2.65
Alkalies (by difference) ($K_2\ O$ & $Na_2\ O$)	3.57
Loss on ignition	.27
	100.00

The microscopical examination and the chemical analyses have shown the Index granite to be composed principally of very stable minerals. It is true there is considerable hornblende, and this is not as stable as some other minerals, but the quartz and feldspar form the larger part of the rock. Reference to Table II., shows the specific gravity of this granite to be 2.743, which is a little higher than that of the other granites being quarried in Washington at the present time. The same table shows the ratio of absorption to be .411 of 1 per cent of the mass of the rock, while the pore space or porosity is 1.308 per cent of the total mass.

The samples used to determine the specific gravity and porosity were alternately frozen and thawed, each day for twenty days, and the loss in weight carefully ascertained. The loss in weight as shown by Table III, was .035 grams or .041 of 1 per cent of dry weight of the stone. This loss in weight was due to the breaking off of small particles, which may have been partially loosened in the preparation of the samples. The same sample after freezing showed no signs of injury so far as could be detected by the eye, and it was not possible to test its crushing strength and compare it with the unfrozen sample.

Cubes of this granite with two-inch faces were prepared in the same way as those of the Snake river granite and used for making the crushing strength tests, and for determining the modulus of elasticity. The results of these tests are shown in Table I. The crushing strength of this stone as shown by the tests made ranges from 13,900 to 16,610 pounds to the square inch, while the modulus of elasticity is from 2,463,000 to 44,444,000 pounds to the square inch. This is practically the same as the crushing strength of the Snake river granite but a little higher than that from the Little Spokane river.

Tests were made to show the effects of high temperature by placing samples in a muffle furnace and gradually heating to a temperature of 800° F. Samples after having been at this temperature and cooled were very much weakened and crumbled on the edges, while those that were at a tempera-

ture of 1,200° F. to 1,600° F. were practically destroyed. Specimens of this granite when heated to 800° F., and cooled suddenly are completely destroyed and can be crumbled to pieces between the fingers. The peculiar sound that is given by granite, which has been heated to high temperatures, when scratched, was very noticeable in this case. The color was not changed by extreme heat.

This granite is not susceptible of a good polish and hence is suitable only for places where rough or dressed but not polished stone is used.

Ellis Quarry.—Mr. T. S. Ellis of Seattle has recently opened a new granite quarry about one-half a mile east of Index in Sec. 20, T. 27 N., R. 10 E. The stone from this quarry is practically the same as that from the Soderbery quarry. The stone from this quarry has been used principally in Seattle. The quarry is situated by the side of the railroad and a short side-track has been built and the stone is loaded right from the quarry on to the cars so that the minimum expense is incurred in getting the stone on board the cars. Should the demand in western Washington for granite as a building stone continue to increase, and it probably will, both of these Index quarries should in the near future, be much better developed than they are at present, as they are well situated, as regards the railroad, and in other respects also, for being worked at a minimum expense. In 1902 the Ellis quarry produced about $10,000 worth of stone, most of which was used in Seattle.

Little Spokane Area.

Washington Monumental and Cut Stone Co.—The quarry of this company is situated about nine miles north and a little west of Spokane on the Little Spokane river. The quarry is in Sec. 34, T. 27 N., R. 42 E., and is 2,300 feet above sea level or 400 feet above the river at Spokane. The quarry is very easy of access as there are no steep grades and a good wagon road passes by it. The highest ridges of the granite here are 2,889 feet above sea level or 589 feet above the present quarry.

A number of quarries have been opened along the side of the hill here and considerable stone quarried at different times. None of these quarries are worked continuously but the stone is quarried only when orders are received for it, except what little is used for monumental purposes by this company. The granite here is separated more or less into blocks by two well defined sets of joints which intersect at almost right angles. The size of these blocks varies considerable, in some cases being as much as six or eight feet in thickness and much longer even than this. The stone is quarried by having holes drilled at a point some distance up the side of the mountain above the quarry yard and then a large mass is broken loose by means of powder and thrown down to the foot of the hill, after which it is worked into proper sizes. The stone resists the atmospheric agencies well and is weathered but slowly. It is well situated for economic quarrying and the quarry should in the near future be much more extensively worked than it is at present. This stone is well suited for all kinds of building purposes, for curbing, and for monumental work and much of it is being used at present by the company for this latter purpose.

This company has a plant in Spokane for working stone which is equipped with a gang saw for sawing marbles and the softer grades of stone, a granite polishing machine, an air compressor for pneumatic hammers, and a traveling crane having a capacity of fifteen tons. The yard is also supplied with a large derrick for handling the stone. At the present time the machinery is being driven by a twenty-two and a half horse power electric motor.

Thin sections of the granite from the Little Spokane river examined under the microscope show the rock to be made up principally of quartz, feldspar, and mica. The grains vary considerably in size ranging from those that are quite small to those that are several millimeters in diameter. The quartz and feldspar are the most abundant minerals in this granite and they are about equally divided throughout the sections. The feldspar is principally plagioclase and has a light color, but occasionally orthoclase crystals occur. Viewed

under ordinary light the feldspar has somewhat of a dirty appearance, and some of the crystals show the zonal structure fairly well developed.

The quartz particles have many seams in them which show very plainly under the microscope. The quartz has a very slight smoky tinge and is glossy appearing. The color of the rock is due to the mingling of this slightly colored quartz, the light colored feldspar, and the mica. Both muscovite and biotite occur in the granite from this locality. The twinning so common to the feldspars is shown in sections of this rock but it is not so common as it is in the granite from Index. The minerals all have very irregular outlines and interlock in a very intricate manner.

The following chemical analysis of a sample of the granite from the above quarry shows it to have the following composition:

Silica ($Si\ O_2$)	71.98
Iron ($Fe_2\ O_3$)	2.69
Alumina ($Al_2\ O_3$)	15.07
Lime ($Ca\ O$)	2.46
Magnesia ($Mg\ O$)	0.58
Alkalies (by difference) ($K_2\ O$ & $Na_2\ O$)	6.92
Loss on ignition	0.20
	100.00

From the above analysis it is seen that this granite is high in silica and alumina and low in iron, lime, and magnesia.

The specific gravity of this granite as shown in Table II, is 2.679 which is almost exactly the same as that of the Medical Lake and Snake river granite. As shown by the same table the weight of water absorbed, by a sample of this granite weighing 98.7 grams, was .685 of a gram and the ratio of absorption was .69 of 1 per cent of the mass of the stone while the porosity is 1.843 per cent of the entire mass.

Two samples of this granite were cut into two-inch cubes by the owners of the quarry and used in making the tests of crushing strength and modulus of elasticity. These samples were prepared by cutting with hammer and chisel and then rubbing the faces smooth and the samples may have been

slightly weakened. The two cubes tested, as shown in Table I., had a crushing strength of 12,870 and 15,800 pounds to the square inch, and a modulus of elasticity of 1,800,000 and 2,058,000 pounds to the square inch respectively. This granite has about the same strength as the other granites being quarried in Washington, but is considerable lower than that of many of the best granites being quarried in different parts of the United States.

Samples were tested to show the effects of freezing and thawing by having them alternately frozen and thawed each day for a period of twenty days, and the loss in weight determined. The result of this test is shown in Table III., to be .07 of a gram on a sample weighing 98.7 grams or .07 of 1 per cent of the whole mass of the stone. No visible cracks were developed and so far as could be told without actual tests the stone was very little weakened.

Tests were made to determine the effect of extreme heat by placing samples in a mufflle furnace and gradually heating to a temprature of 800° F. and then allowing the samples to cool in the open air. The samples when cooled were found to be very much weakened and could be easily crumbled on the corners and edges. One sample was cooled suddenly from a temperature of 800° F., by being plunged into cold water and in this case the strength was completely destroyed. At 1,200° F. even with slow cooling the stone was completely destroyed. At these high temperatures the color of the stone was slightly changed becoming a little lighter.

This granite takes a high polish and is being used to a considerable extent for monumental purposes as well as for all kinds of work where rough or dressed granite is desired.

MEDICAL LAKE AREA

Giles and Peat Quarry.—The only granite quarry being operated at the present time (Sept. 1902) in this area, is owned by Messrs. Giles and Peat, and located on the west shore of Medical Lake, about thirteen miles west of Spokane. It is on the line of the Central Washington Railway, which

GRANITE QUARRY OF WASHINGTON MONUMENTAL AND CUT STONE COMPANY, LITTLE SPOKANE RIVER.

GRANITE QUARRY OF GILES AND PEAT, MEDICAL LAKE.

is a branch of the Northern Pacific, and distant from Spokane twenty-six miles. It is in Sec. 18, T. 24 N., R. 41 E.

The stone being quarried at Medical Lake is a light gray colored, biotite granite, and a very firm and solid stone. It comes through the basalt at this place, and is entirely surrounded by it. The granite is being quarried along the west bank of the lake while on the east bank the basalt occurs. The granite forms a bluff along the lake which reaches an altitude above the lake of about fifty feet. The quarry is operated entirely by hand and is not worked continuously but only to fill orders as they are received. The stone is first blasted out with black powder and then worked into shapes and sizes by hand. One set of joints in the stone here appears to be almost horizontal and near the surface especially these joints are close together. The stone is a fair one to work, splitting quite straight and regular, but on account of its hardness it is not quite so quickly shaped as some granites. It resists the atmospheric agencies well and weathers but slowly as is shown by the granite in the quarry and in buildings where it has been used. At the present time a force of men is at work filling an order for stone for Fort Wright, near Spokane.

From the quarry the stone is hauled by teams about one-half a mile to the railroad where it is loaded on the cars and shipped to various places. This quarry has been in operation at intervals for a number of years and stone from here has been used in a number of the state buildings, such as the Administration building of the State University; the Administration building of the Agricultural College and School of Science, and the Medical Lake Insane Asylum. It is also used for street curbing and for gutters and in small amounts for monumental work. The quality of the stone and the accessibility of it should cause the demand to constantly increase and in a few years the quarry should be operated on a much larger scale.

A thin section of the granite from Medical Lake examined under the microscope shows that this rock is composed essentially of quartz, feldspar, and mica. The individual grains

vary somewhat in size but not so much as those of the granite from the Little Spokane river and on the average they are smaller also. While quartz and feldspar are the most important minerals in this granite at the same time the biotite is quite common. The feldspar is the most abundant mineral in this rock composing a little more than one-half of the entire mass. The orthoclase and plagioclase feldspars both occur in this granite.

When viewed under ordinary light the feldspars have a dirty appearance, which is very marked in this case. Twinning is quite common also as shown by the sections and in places zonal structure is quite prominent. The quartz crystals under the microscope are quite clear and transparent but in the rock mass they have a faint smoky tinge. The feldspar is light colored with a very slight pinkish tinge in places. The mica is quite a prominent constituent of this rock and is of the biotite or black variety. The minerals all have more or less irregular outlines and interlock in an intricate manner.

The following chemical analysis shows the composition of the granite being quarried at Medical Lake:

Silica ($Si\ O_2$)	68.24
Iron ($Fe_2\ O_3$)	3.50
Alumina ($Al_2\ O_3$)	16.30
Lime ($Ca\ O$)	3.20
Magnesia ($Mg\ O$)	1.88
Alkalies (by difference) ($K_2\ O$ & $Na_2\ O$)	6.40
Loss on ignition	0.48
	100.00

The above analysis shows this granite to be a little below the average in silica but with that exception it has about the composition of a normal or average granite.

Samples of the Medical Lake granite were tested to determine the effects of changes of temperature by being alternately frozen and thawed each day for a period of twenty days and the result as regards loss of weight is shown in Table III. A sample of this stone weighing 102.062 grams had lost at the end of the twenty days .062 grams or .06 of 1 per cent of its entire mass. Samples were also tested to

show the absorptive power and porosity of the stone and it was found that a sample weighing 102.062 grams absorbed .562 grams of water and had a ratio of absorption of .55 of 1 per cent and a percentage of pore space or porosity of 1.452 of 1 per cent of the mass of the stone. The specific gravity of the Medical Lake granite was found to be 2.676 which is the same as the specific gravity of that from the Snake river and the Little Spokane river.

Samples if this stone were placed in a muffle furnace and gradually heated to a temperature of 800° F. and some of the samples cooled suddenly by being plunged into cold water while the others were allowed to cool slowly. In the case of those that were cooled suddenly the strength was practically destroyed throughout the entire sample and it could be easily crumbled to pieces between the fingers. Those samples that were allowed to cool slowly crumbled easily on the edges only. Samples were then heated to a temperature of 1,200° F., and when cooled were found to be practically ruined as their strength was almost all gone. This high temperature caused the stone to change color somewhat the feldspar becoming of a pinkish color. The mica had more of a brassy appearance than it had before heating and the quartz was whiter. It had when struck that characteristic ring peculiar to granite after having been highly heated.

The Medical Lake granite is susceptible of a good polish and is suitable for all kinds of monumental work as well as for building and all kinds of masonry work.

Conclusions.

From the tests made in the preparation of this report certain conclusions may be drawn as regards the quality of Washington granite at least that being quarried at the present time. The industry in Washington is in its infancy and in the course of a few years it is very probable that many new quarries will be developed as well as the present ones being much more extensively worked. A comparison of the strength of the Washington granite with that of the granite from other places indicates that the Washington granite

is below the average. This, however, does not hinder it from being a good building stone since as has already been shown in this report stone for building purposes is never subjected to more than from one-tenth to one-twentieth of the weight it will support and for the tallest buildings this is estimated to not exceed 3,146 pounds to the square inch.*

The specific gravity is practically the same as that of the best granites found in the United States and while the ratio of absorption is higher than that of some of the best granites at the same time it is not as high as that of others. The percentage of pore space or porosity is above the average for granites. Some of these granites take a very good polish and are being used to a certain extent for monumental purposes. The stone does not vary much in color being in all cases a rather light gray. While the granite being quarried at the present time in Washington is not so good as some of the granites being produced in other localities it is undoubtedly a very fair granite and is well suited for building purposes and as the state becomes more thickly populated and the cities become larger the demand for granite will be very much greater than at present and this demand should be largely supplied by stone produced at home.

TUFA.

The term tufa or tuff includes those rocks that are composed of fragmental volcanic material such as ashes, sand, and lapilli and which have been more or less consolidated. The material of which they are composed has in some cases also been derived from the breaking down and decomposing of volcanic rocks of various kinds. These rocks are generally more or less stratified and in many cases stratification is very marked showing that beyond doubt they have been accumulated in water. The degree of consolidation of these tufas varies considerably and some of those that are of very recent formation geologically and some of those that are of very recent formation geologically are quite soft and not well compacted.

*[illegible] Building [illegible] Stones of Wisconsin, p. 46.

Tufa has been used somewhat in certain localities as a building material but up to the present time it has not come into any very general use, for that purpose, in the United States. It occurs quite plentifully especially in many parts of the west. Tufa has been quarried at two different localities in Washington as follows: Near Lilliwaup on Hoods Canal, and at China Bend in Stevens County. Very little work, however, is being done at the present time at either of these places.

Lilliwaup Area.

The only stone quarry that has been operated in this area is about two miles north east of Hoodsport on the west side of Hoods Canal and about eight miles from the southern end of the canal. The quarry, at the time it was being operated, was known as the Lilliwaup Stone Quarry. The property is owned by Mr. C. J. Sund and is situated in Sec. 31, T. 23 N., R. 3 W. in the foot hills of the Olympic mountains, and while it is probably about eighty miles from Seattle at the same time it is very easy of access, and being situated on Hood's Canal, which is a deep water channel, it would have very cheap transportation and could be laid down in Seattle at a very reasonable figure.

Some work has been done here toward opening up a quarry, but at the present time (Aug., 1901) nothing is being done A few scow loads of stone have been quarried here and used in Seattle. This material was quarried and marketed as a sandstone, but it is not a sandstone at all, being a tuff instead. The material occurs in stratified deposits which are dipping to the east at an angle of about 62°. The deposits outcrop along the beach for at least two and one-half miles and may extend much farther, but are covered by deposits of gravel, which are very common through that locality. The strata composing the deposit vary much in thickness and range from those that are only a few inches up to those that are as much as four feet. They also vary somewhat in texture, in some places being quite fine grained, while in others they are coarse grained.

The microscopical examination of this rock was kindly made and the following description prepared by Professor J. P. Iddings, of the University of Chicago:

"An indurated tuff of hornblende-pyroxene-andesite."

"It looks like a finely brecciated andesite somewhat altered. The rock consists of a ground mass, which is microcrypto-crystalline, with disseminated chlorite, giving a greenish tinge to the rock. The crystals scattered through the ground mass, appearing as very small phenocrysts, are mostly plagioclase feldspar slightly altered and whitened. There are smaller crystals of pyroxene—mostly augite—and pleochroic hornblende, with some magnetite. There appear to be a few crystals of quartz with glass inclusions."

The following chemical analysis shows the composition of the Lilliwaup stone:

Silica ($Si\ O_2$)	60.58
Ferric iron ($Fe_2\ O_3$)	7.90
Alumina ($Al_2\ O_3$)	18.42
Lime ($Ca\ O$)	8.16
Magnesia ($Mg\ O$)	1.53
Water at 110° C. ($H_2\ O$)	1.81
Loss on ignition	1.83
	100.23

The above analysis shows this tufa to have about an average amount of silica for an andesite, the amount of iron, alumina and calcium is high, the amount of magnesia is small, while the sodium and potassium are entirely absent. The sample if a true andesitic tufa should contain from two to six or seven per cent. of potash and soda together. It is possible, however, that in this case the feldspar which occurs in this particular sample may be anorthite.

Two cubes, each having two-inch faces, of this tufa from Lilliwaup Falls were tested to determine its crushing strength and as shown in Table I. they resisted a pressure of 10,300 and 11,590 pounds to the square inch respectively. The modulus of elasticity was determined on these same samples, and as shown by the same table was 3,576,000 and 2,664,000 pounds to the square inch. These tests show this stone to have a crushing strength considerably below that of the granites being quarried in Washington.

Tests were made to show the ratio of absorption and porosity of this stone, and as shown in Table II. the amount of water absorbed by a sample of this stone weighing 43.749 grammes was 2.031 grammes, and the ratio of absorption was 4.64% of 1% of the mass of the rock, while the percentage of pore space or porosity was found to be 11.235 of the rock. The specific gravity of this rock as shown by the same table was found to be 2.726. Tests were also made on this stone to determine the effect of alternate freezing and thawing each day for a period of twenty days and the loss in weight carefully determined, and it was found that the sample had lost .134 of 1% of its weight.

The stone from this locality was tested to show its ability to withstand high temperatures by placing a sample in a muffle furnace and heating gradually to a temperature of 800° F., when the sample was taken from the furnace and plunged into cold water and left there until it had cooled, and so far as could be told it had not been injured in the least. Samples were also heated to 1200° F. and 1600° F., and when cooled were apparently uninjured. The color of the samples was changed by these high temperatures from a dark gray to almost a brick red. This test shows that this stone has the property of resisting high temperatures and sudden changes in temperature extremely well. Granites from the Little Spokane river under the same conditions exactly would be completely destroyed when the Lilliwaup stone would be unaffected and when cold it would be as strong as it was before it had been heated.

CHINA BEND AREA.

What is known as China Bend is on the Columbia river 119 miles north, and a short distance west, of Spokane. The Spokane Falls and Northern Railroad in following the river at this point and gives an easy way of marketing any stone that may be quarried here. Situated within one-half mile of the railway is a rock which has the appearance of a sedimentary deposit and which is commonly spoken of as sandstone. This same kind of material is also found seven miles northeast from

Bossburg in Sec. 30, T. 38 N., R. 39 E., where the Washington Monumental and Cut Stone Co. are intending to open up a quarry and have already done some work and shipped a little of the stone to their mill in Spokane.

There has been some work done on this material at China Bend and some stone has been shipped from there to Spokane, but at the present time (July, 1902) no work is being done. This material is not, as is generally supposed, a sandstone, but is a tuff or tufa. The deposit is more or less bedded, the layers varying much in thickness. The material varies considerably in texture from that which is very fine to that which is quite coarse. The material is light gray in color and of medium hardness. The deposits are quite extensive, but the exact extent has not been determined.

The following microscopical examination was made and the description prepared by Professor J. P. Iddings, of the University of Chicago:

"The rock is a fine, indurated tuff of dacite material. The section shows abundant crystals and broken fragments of crystals and fragments of glassy ground mass, with a slight admixture of what may be foreign rock material.

The crystals are mostly plagioclase feldspar, having the characteristics of feldspars in volcanic lavas—glass inclusions, marked zonal structure, and quite fresh substance. Some of them have the optical properties of labradorite. No sanidine was identified definitely as such. It may be present in very small amount. There are numerous fragments of crystals of quartz, some with glass inclusions, some with fluid inclusions, as though they had been derived from fragments of granite, but there are evidences of the minerals in the indurated tuff having been crushed, and the observed fluid inclusions may be secondary in volcanic quartzes. Other minerals which are present in very subordinate amounts are: Biotite, pyroxene, magnetite, minute fragments of epidote(?), titanite, pyrite, apatite, and zircon. Through the rock are scattered particles of red oxide of iron, which give a reddish color to the thin section not noticed in the hand specimen. The red color may have been brought out by heating the specimen in balsam.

There are patches of calcite scattered through the rock, together with an isotropic mineral (possibly analcite). This is quite sporadic and possibly not worth mentioning. The ground mass is glass for the most part, and constitutes one-fourth of the rock. It is in places microcryptocrystalline, and in places contains a little chlorite.

The rock is a fine grained tuff derived from fragments of dacite."

The following chemical analysis shows the composition of the rock from this locality:

Silica ($Si O_2$)	65.34
Ferric iron ($Fe_2 O_3$)	8.51
Alumina ($Al_2 O_3$)	13.01
Lime ($Ca O$)	6.30
Magnesia ($Mg O$)	0.53
Water at 110° C. ($H_2 O$)	Trace
Loss on ignition	1.17
Alkalies and undetermined	5.14
	100.00

The above analysis shows this rock to have about the average composition of a dacite. The silica, alumina and magnesia are perhaps a trifle below the average, while the iron and lime are a little higher than is usual for a typical dacite. The potash and soda are about normal.

Tests were made on samples of the Bossburg tufa to determine its crushing strength, and the results are shown in Table I. Two cubes were tested and found to have a crushing strength of 7,730 and 9,300 pounds to the square inch and a modulus of elasticity of 6,550,000 and 1,320,000 pounds to the square inch respectively. As shown in Table II., this stone has a specific gravity of 2.621, and a sample weighing 81.975 grammes absorbed 6.445 grammes of water, or 7.86% of its entire weight. The pore space or porosity was found to be 17.075% of the entire mass of the stone.

Samples were tested to show the effects of freezing and thawing on this stone, by being saturated with water and then alternately frozen and thawed each day for a period of twenty days and the loss of weight carefully determined. As shown in Table III., the loss of weight of a sample weighing 81,975

grammes was .244 grammes, or .297 of 1% of the mass of the stone.

The stone tested from this locality to show the effects of high temperature was from the property of the Washington Monumental and Cut Stone Co., near Bossburg. Samples were placed in a muffle furnace and gradually heated to a temperature of 800° F., and some of them were allowed to cool gradually, while others were cooled suddenly by being plunged into cold water. In neither case were the samples injured materially so far as could be told, and they did not crumble even on the edges as the granite and sandstone did. The color was changed to a reddish tinge. Samples were then heated to temperatures of 1200 F. and 1600 F., and while in appearance they were not very much injured, when they were tested it was found that their strength was very much less than before being heated, and in those samples that had been at a temperature of 1600° F. it was practically gone.

From the above it will be seen that this stone does not resist heat so well as the Lilliwaup tufa, but at the same time it will stand heat better than the granites and some of the sandstones found in Washington. The color of this stone is more pleasing than that of most of the sandstones which occur in this state. The physical tests show that the stone has many of the qualities of a good building stone, and eventually as the demand for stone increases it will probably be used to a considerable extent.

BASALT.

Through all of Southeastern Washington the prevailing country rock is basalt, and this is used to a considerable extent in many places for building purposes and especially for rough work and for foundations. The basalt varies much in texture in different places, being in some cases quite coarse, while in others it is very fine grained and compact. Then again in places it is full of cavities, which range in size from those that are a millimeter or two in diameter to those that are as much as a fourth of an inch in diameter, and sometimes even more. Where fresh and undecayed it has a very dark, almost black, color. This changes on weathering to a more or less reddish

cast on account of the iron which it contains. When placed in buildings it should resist the action of the atmospheric agencies quite well and weather rather slowly.

The basalt as a general thing is quite badly broken to pieces by joints and it is frequently very difficult to obtain very large blocks. The stone is quite hard, also, and this makes it difficult to quarry and work into dimensions after it is quarried. The one thing that causes it to be used as much as it is as present is its accessibility, as all that is necessary is to go out almost any place and quarry it, and on this account the item of transportation does not enter in to increase its final cost to so great an extent as it does in the case of many building stones. While it is true that basalt is not a first class building material, it will probably always be used more or less, for the reasons just given, through this part of Washington, especially for foundations and various kinds of rough masonry. Some very nice foundations are built out of it and the first story of Morrill Hall, the new chemical laboratory of the Washington Agricultural College and School of Science, is constructed of this material.

Hale and Kern Quarry.—The Hale and Kern Contract Company of Portland, Oregon, operate a stone quarry at what is known as Fisher's Landing, ten miles above Vancouver, on the Columbia river. The stone being quarried at this place differs in color and texture from the basalt which is above and below it. It is much lighter colored and is a fine grained, compact stone which is quite easily worked. This stone has been used to a considerable extent in foundations and for bridge piers. The larger part of the stone so far quarried at this place has been used in making the jetties at the mouth of the Columbia river and at Gray's Harbor. The output for 1901 was 220,000 tons. About 1,000,000 tons have been used at the mouth of the Columbia and about 500,000 tons at Gray's Harbor. The color and texture of this rock would seem to indicate that it might be quite a valuable building material, especially for foundations and that class of work.

CHAPTER IV.

SANDSTONES OF WASHINGTON.

DISTRIBUTION.

The sandstones of Washington are quite widely distributed geographically and occur in a number of the counties of the state. The principal deposits are found on the western side of the Cascade mountains. There are deposits on the eastern side of the range, also, and especially around Clealum and to the north. Building material has not been quarried, to any extent at least, from these deposits. In Western Washington sandstone occurs at many places about the borders of Puget Sound and to the south of it. The principal quarries are in Whatcom, King, Pierce and Thurston counties. Quarries have been operated at different times in other places and especially on Sucia Island, in San Juan county, where quite an extensive quarry was being operated at one time.

The sandstones of Washington range geologically from possibly as far back as Carboniferous up to very late Tertiary. The oldest sandstones so far known are on the east side of the Cascade mountains in the northern part of the state. Russell * in speaking these has the following to say:

"The unmetamorphosed pre-Tertiary sediments, represented by conglomerates, sandstones, shales, limestones, etc., embraced principally in the Similkameen, Ventura and Winthrop formations exposed over extensive areas near the Canadian boundary, are believed to be in part Carboniferous, but mainly of Mesozoic age. This conclusion, however, is based on a small number of fossils, and is tentative."

Tertiary sandstones also are found on the east side of the Cascades, especially at Roslyn and Clealum.

The coarse sandstones and conglomerates which occur on a number of the islands of the San Juan group are of Cretaceous age. They vary considerably in color and range from

* 20th Annual Report U. S. G. S., Part II., p. 128.

CHANNELER AT WORK, TENINO SANDSTONE QUARRY.

CARVED WORK, TENINO SANDSTONE.

gray to various shades of brown. On Waldron island it forms cliffs 200 to 300 feet high along the shore. It also occurs on Sucia, Matia, Spieden, Stuart and the northern part of Orcas island.

Along the borders of Puget Sound and the foothills of the Cascades in Western Washington tertiary sandstones are found in many places. These tertiary sandstones are quite variable in color, texture and hardness. In color they vary from light gray to a dark bluish or greenish, with various shades between these extremes. In texture they range from very fine to very coarse grained. The stone in general is not so hard that it is difficult to work, but on the other hand, is easily quarried and worked into almost any shapes desired.

Tenino Area.

Tenino Stone Quarry Company.—The quarry of the Tenino Stone Company is in Sec. 19, T. 16 N., R. 1 W. The main line of the N. P. Ry. from Tacoma to Portland passes by the quarry and a short spur has been built from the main line to the mill, so that cars can be run in along by the side of the mill and quarry and the stone loaded directly onto them from the quarry. The quarry and works of the company are situated in the town of Tenino, about 12 miles south and 4 miles east of Olympia. The country around Tenino is a gravel prairie, with low hills rising above it, especially on the east. The hill in which the quarry is located is not more than 100 feet above the valley.

The Tenino sandstone is a finer grained and darker colored stone than the Cumberland or Wilkeson stone. It is quite fine grained, contains some mica, is well cemented, and has the property of hardening after being quarried, which is a very valuable property of a building stone. The deposit has been opened in three different places by this company, two of which have been worked down to water level. The different openings are about as follows in size or dimensions: 215 feet long, 100 feet wide, and 60 feet deep. This opening is not being worked at present, but is used as a reservoir. There is another opening 200 feet long, 100 feet wide, and 40 feet deep.

This is the principal one being worked at present. Still another small opening has been made higher up the hill above both of these, but no very large amount of stone has been taken from this last opening. The stone is the same from all of these different openings. The stone in this deposit occurs in a somewhat massive form, there being no marked stratification planes separating the stone into layers. It does have stratification planes which are almost horizontal, and the stone splits along these more readily than it does across them. Cross bedding is a very prominent feature of a large part of this deposit and shows very distinctly in the stone after it has been sawed. The deposit lies almost horizontal, dipping only a few degrees to the southwest, and this makes it easy to work.

This company has prospected its deposit with a diamond drill with the following results: The stone that is being worked at present was found to continue for 88 feet below the surface; just below this a layer 12 feet in thickness was found which was lighter colored and resembled very much the Cumberland sandstone in color, but finer grained than either that or the Wilkeson stone; at 100 feet the color was dark again; at 135 feet the color is dark, but the stone is finer grained again and continues dark colored and fine grained to a depth of 200 feet, which was as deep as the company bored. From 174 feet on down to 200 more or less clay is mixed with the sand. The Tenino Stone Quarry Company owns 120 acres of these deposits.

The company has a very complete plant for working this stone and a large part of the work is done by machinery. At the present time (Aug., 1901) forty men are employed, and in July, 1901, $4,600.00 worth of stone was shipped. During the busiest part of the year the shipments will probably average $4,000.00 per month and for the remainder of the year perhaps $2,000.00 a month. The stone is quarried by first getting a working floor, on which tracks are laid for the use of the channeling machines. The company has two of these machines, one of which is 4½ feet wide and the other 6½ feet wide. By means of the channelers large blocks of sandstone are cut along two and sometimes along three sides and

then broken loose on the other by wedging. In this way very large blocks of regular sizes are obtained. These large blocks are hoisted from the quarry to the level of the mill by means of steam derricks, placed with their bedding planes vertical on small cars, and taken to the mill, where they are sawed into the various sizes wanted. The company employs from 10 to 15 skilled stone cutters and is prepared to furnish all kinds of carved and ornamental work as well as plain dimension stone.

The mill is supplied with four gang saws for cutting the stone, with the following dimensions: 18½x5½ feet, 11½x8 feet, and 12½x5½ feet. These saws are capable of cutting blocks 16x6x5½ feet in size. They are run at different rates of speed and hence the rate of cutting is different even on the same size blocks, some of them cutting 6 inches per hour, while one will cut as high as 24 inches per hour. The abrasive used in sawing these sandstones is coarse steel filings, which are fed into the grooves along with water. The saw is driven by a rod connected directly with the piston of a steam cylinder. The power for driving the machinery is furnished by a 55 horse power return flue boiler, and a 50 horse power Erie engine. There are also two large steam hoists for operating the derricks in handling the stone. The mill is supplied also with one steam polisher, which is used in finishing window sills and work of that character. The custom here, as in many other places, is to cut the stone to the proper sizes, ready to place in the building, and in this way save paying freight on waste material.

A thin section of the sandstone from the Tenino quarries examined under the microscope shows that the individual grains, as a general thing, are angular in outline, with very sharp corners. The grains of sand vary considerably in size throughout the stone.

This stone consists principally of fine grains of quartz, that have been worn and rounded but little, with occasional small flakes of mica scattered through the mass. The grains are small and are cemented together with a ferruginous cement which holds them quite firmly. The stone from here is finer

grained than the Wilkeson and Cumberland stone. There are a very few crystals of feldspar found in the sections examined.

The following analysis shows the rock from this locality to have more iron and alumina than the Wilkeson sandstone, and to this fact is probably due its darker color. The amount of iron, however, is not large even in this sample. The composition of the stone shows it to be one that should resist weathering well:

Silica ($Si O_2$)	90.84
Iron ($Fe_2 O_3$)	3.38
Alumina ($Al_2 O_3$)	1.85
Lime ($Ca O$)	0.65
Magnesia ($Mg O$)	1.02
Loss on ignition	2.2
	100.03

Cubes of the stone from the quarry having two-inch faces were tested to show its crushing strength and modulus of elasticity, and as shown in Table I. it ranged in crushing strength from 3,270, on edge, to 5,750 pounds to the square inch on bed, with a modulus of elasticity of from 551,000 to 1,288,600 pounds to the square inch. This is a little lower than was obtained by the ordnance department of the United States army on a sample tested at the Watertown arsenal July 3, 1893, the result of which was 6,879 pounds to the square inch.*

The Tenino stone, as shown in Table II., was found to have a specific gravity of 2.861, a ratio of absorption of 8.21% and a pore space or porosity of 18.001% of the mass of the stone. It showed a loss in weight, after having been alternately frozen and thawed each day for a period of twenty days, of .266 of 1% of its entire weight. This loss was due to loosening of grains on the edges and to the complete loosening of grains that were partly loosened in the preparation of the sample.

Samples were tested to show the effects of extreme heat by being placed in a muffle furnace and gradually heated to a temperature of 800° F. and some of the samples were cooled by being taken from the furnace, and while still hot they were

* Washington Geological Survey, Annual Report, 1901, p. 168.

HIGH SCHOOL BUILDING, SEATTLE, MADE OF TENINO SANDSTONE.

TRINITY CHURCH, SEATTLE, MADE OF CUMBERLAND SANDSTONE.

put into cold water and allowed to remain until completely cooled, while others were cooled slowly. The samples that were cooled slowly were apparently uninjured, while those that were cooled quickly crumbled a little on the edges. Samples were then heated to a temperature of 1200° F. and 1600° F., and when cooled gradually did not appear to be much affected, but when tested they were found to be very much weakened and their strength practically destroyed. The color of the stone was changed to a brick red by the heat.

The foregoing results show the Tenino stone to be below the average in crushing strength, to have a high ratio of absorption, and high percentage of pore space or porosity. The strength of the stone, however, is ample for all building purposes. The stone is not as hard as some sandstones and yet is hard enough to resist wear well. The stone when first quarried is very easily worked, and as has already been mentioned, becomes very much harder after being exposed to the atmosphere for some time. This hardening is due principally to a loss of water.

These quarries were first opened up in 1889 and since that time the output has been practically continuous and gradually increasing in amount. The stone is of Eocene age and in places near by coal is found. This stone has been used in many large buildings throughout the state and in Oregon and California as well. It is used not only as a finishing material, but as the principal material of construction also. It is being used in the addition to the State Capitol now being built, and has been used in such structures as the Bailey building in Seattle, the Calvary Presbyterian Church in San Francisco, and some of the principal business blocks in the larger coast cities. The fineness of the grain of this stone and the ease with which it may be cut make it a very superior stone for all kinds of carved work where sandstone is used.

Eureka Sandstone Company.—The property of this company is one mile east and a little north of Tenino. The quarry is reached by a spur of the Northern Pacific Railway which leaves the main line a short distance east of Tenino.

The stone is practically the same as that being quarried

at Tenino, except that perhaps it contains more iron nodules and sand pockets. These sand pockets, as they are called, are places where there are masses of loose or unconsolidated sand, and they vary in size and shape from small, spherical masses up to those three and four inches in diameter; others, again, are irregular in shape. The hill in which the quarry is located rises about 150 feet above Tenino. The deposits here show very little signs of stratification. This quarry is not being operated at the present time (July, 1901) and has not been for the past eight years. At one time, however, a large force of men was employed and the quarry worked in a very systematic way. A large part of the stone quarried here has been used by the N. P. Ry. for bridges, but some building stone also has been shipped from this place. The quarry at the time it was closed down had a working floor 100x200 feet and a vertical face 50 feet high and 200 feet long.

The stone for some distance below the surface is of rather poor quality, but improves with depth. This poorer stone was crushed and used in concrete foundations for building and for bridge piers.

The quarry was well supplied with machinery for operating it economically, and most of it has been well cared for since the quarry was closed. In the mill are three gang saws for sawing the stone, and a 40 H. P. Atlas engine and boiler furnished the power for driving them. In the yard are powerful derricks and a hoisting engine for handling the stone. Two channelers were used in the quarry and at present are stored in the mill.

The buildings are in good condition, everything is being well cared for, and quarrying could be begun at any time without the expending of very much money.

Bellingham Bay Area.

Chuckanut Quarries.—These quarries are about three miles south of Fairhaven and are in Secs. 13 and 24, T. 37 N., R. 2 E. The quarry is situated on the water front on Chuckanut Bay and extends for a distance of 1¼ miles along the bay. The harbor is said to be a good one and the stone is

easily loaded direct from the quarry yard to barges or boats. The quarry is well situated for very cheap transportation, especially to all points on Puget Sound. The Great Northern Railroad passes through the quarry yard and this gives another means of transportation for the stone.

The Chuckanut sandstone is a fine grained, dark colored, well cemented stone. The deposit that has been worked here is about 40 feet thick, and below this a shale occurs the thickness of which is not known, as it has not been prospected. The strike of the deposit is N. 10° W. The stone is broken down in large masses by blasting and then worked into dimension stone by wedging and sawing. Three distinct grades of stone are found in this deposit, two of which are due simply to the size of the sand grains which have been cemented together, while the third is known as flagging stone on account of the fact that it splits easily in certain directions, giving good flagging blocks. This stone is somewhat harder than the Tenino stone, but at the same time it is not so hard but that it is easily worked.

Tests made by the Ordnance Department, U. S. A., show the stone to have an ultimate strength of from 10,276 to 12,790 pounds to the square inch.

There is a medium sized mill connected with the quarry in which are two gang saws 14 feet by 7 feet. The power for driving these saws is furnished by a 40 horse power boiler and engine. The quarry is also supplied with steam hoist and derricks for handling the stone in the yard.

Sections of the sandstone from Chuckanut examined under the microscope show it to be composed essentially of small grains of quartz and that these grains are very angular and sharp cornered, having been rounded but little as a genertl thing. The individual sand grains vary but little in size, are a little smaller and perhaps a little less rounded than those of the Tenino stone.

The small grains of silica in this sandstone are quite firmly bound together by a ferruginous cement. There are two grades of stone quarried here as far as texture is concerned, the coarser being about the same, or perhaps a little coarser

than the Tenino stone, while the other is much finer. This very fine texture or grain of the Chuckanut stone makes it a very good stone for carved and ornamental work, giving good, sharp edges and perfect outlines.

The following chemical analysis shows the Chuckanut stone to have practically the same chemical composition as the Tenino stone:

Silica ($Si\ O_2$)	90.19
Iron ($Fe_2\ O_3$)	3.50
Alumina ($Al_2\ O_3$)	1.92
Lime (Ca O)	0.59
Magnesia (Mg O)	1.78
Loss on ignition	2.32
	100.30

In the preparation of this report samples of the Chuckanut sandstone were tested to determine its crushing strength and modulus of elasticity and the results are shown in Table I. The samples which were tested on the bed—that is, where the pressure was perpendicular to the bedding planes—showed a crushing strength of 10,740 and 11,070 pounds to the square inch, while the one tested on the edge—that is, where the pressure is parallel to the stratification planes—showed a crushing strength of 5,340 pounds to the square inch. The modulus of elasticity of the samples tested on the bed was 1,517,000 and 1,158,000 pounds to the square inch, and of the one on the edge 871,500 pounds to the square inch.

Samples of this stone were alternately frozen and thawed each day for a period of twenty days and the loss in weight of the samples carefully determined, and as shown in Table III, the loss in weight was .076 of 1% of the entire weight of the sample. The stone has a specific gravity, as shown in Table II., of 2.727, and a sample weighing 65.168 grammes absorbed 2,927 grammes of water, or 4.47% of the weight of the sample, and the percentage of pore space or porosity is 10.91% of the entire mass of the stone.

Samples were tested to show the effects of extreme heat and sudden cooling by placing them in a muffle furnace and gradually heating them to a temperature of 800° F. Some of the samples were cooled suddenly by being taken from the

WHATCOM COUNTY COURT HOUSE, BUILT OF CHUCKANUT SANDSTONE.

CUSTOM HOUSE AND POST OFFICE, PORT TOWNSEND,
BUILT OF CHUCKANUT SANDSTONE.

furnace and while at a temperature of 800° they were put into cold water and allowed to remain until cooled, and they were apparently unaffected by this sudden change even, as the samples would not crumble even on the edges, as the samples from the other localities did. Samples were also heated to temperatures of 1200° F. and 1600° F. and allowed to cool in the open air and the samples then tested, and it was found that the strength of the samples that had been at a temperature of 1600° F. was somewhat weakened. The weakening was principally along the bedding planes, however, and caused the samples to split along these planes more readily than before being heated, but it did not cause them to crumble. The samples that were heated to 1200° F. and then cooled were apparently uninjured and appeared to be as strong as they were before being heated. The color was changed by the heat to a dark red.

The first stone quarried around Chuckanut Bay was in the early seventies and for a number of years the quarries were not operated continuously, but at intervals when orders for stone were received. The last few years, however, the quarries have been operated on a larger scale, and at the present time stone from here is being used in a number of new buildings that are being constructed in Seattle. This stone has been used in such buildings as the U. S. Custom House, Port Townsend; U. S. Custom House, Portland, Oregon; Dexter Horton building, Seattle; Thurston county courthouse, Olympia; and many other of the important buildings in the larger cities of Washington.

Cumberland Area.

Eureka Coal Company.—The quarry of the Eureka Coal Company is situated at Cumberland, a station on the main line of the N. P. Ry., and is about 24 miles due east from Tacoma, being in Sec. 28, T. 21 N., R. 7 E. It is in the foothills of the Cascade mountains and some of the ridges and peaks rise to a considerable distance above sea level. This company also owns and operates coal mines at this place. The quarry was situated on the western side of a high sandstone

hill and was reached from the main line of the railroad by a short spur and gravity tram.

At one time the Eureka deposit was worked quite extensively, but seven years ago it closed down and nothing has been done since. At the time the Eureka quarry was being worked a large part of the stone was being used in Seattle for building purposes. The principal cause for closing the quarry was the very high freight rate charged on the stone. At the time the quarry was in full operation a large force of men was employed.

The stone from this quarry is a light colored, medium grained, quite firmly cemented sandstone in which the cementing material appears to be principally silica. In general the stone is quite free from iron and of a uniform color and texture. In places, however, small seams of carbonaceous material are found, and occasionally iron nodules occur in the stone. There is a vertical face 250 feet high shown at this place and the quantity of stone is practically unlimited.

An examination under the microscope of thin sections of the sandstone from this area shows that it is composed of medium sized grains of silica.

The stone consists essentially of grains of quartz with some muscovite scattered through it. The cementing material is quartz. The grains of quartz are not, as a rule, very much rounded, but instead are angular and sharp cornered and are quite firmly bound together. Small flakes of muscovite are quite common and generally distributed through the rock.

The following chemical analysis shows the rock to be practically free from all substances that have a tendency to disintegrate rapidly and injure the stone:

Silica ($Si\ O_2$)	95.65
Iron ($Fe_2\ O_3$)	0.90
Alumina ($Al_2\ O_3$)	0.06
Lime ($Ca\ O$)	0.65
Magnesia ($Mg\ O$)	0.22
Loss on ignition	1.54
	100.02

Samples of the sandstone from the Eureka quarries were tested for crushing strength and the results of these tests are

shown in Table I. They showed a strength of 3,520 and 3,280 pounds to the square inch and the molulus of elasticity was 712,100 pounds to the square inch. The strength of the Eureka stone as shown by these tests is below the average for sandstone, but I think probably these results do not show the average strength of this stone, as the quarry was not in operation at the time I visited the locality and it was hard to obtain good, fresh samples of the stone.

Samples were tested to see what the effect of freezing and thawing would be and the loss of weight is shown in Table III. These samples were alternately frozen and thawed each day for a period of twenty days, and at the end of the time the loss of weight of the sample of Eureka stone was .313 grams or .635 of 1% of the weight of the sample.

The stone has a specific gravity of 2,628, as shown in Table II. As shown by the same table the ratio of absorption is 5.36%, while the percentage of pore space or porosity of the stone is 12.355%.

Tests were made on this stone to show the effect of extreme heat and sudden changes of temperature. Samples were placed in a muffle furnace and gradually heated to a temperature of 800° F. Some of the samples were taken from the furnace and cooled suddenly by being put into cold water, and when cold the samples were tested as regards strength and crumbled on the edges only. The samples that were allowed to cool gradually were apparently but little affected. Samples were next heated to a temperature of 1200° F. and then to 1600° F., and in each case allowed to cool gradually in the open air. The samples after having cooled from a temperature of 1200° were apparently almost as strong as before. No cracks were visible and the samples crumbled but little on the edges even. After having been heated to 1600° and cooled the stone was considerably weakened, but the strength was not entirely gone, as it was in the case of the granites. The color was practically unchanged. The samples when scratched or struck with anything, after being heated, gave off a sound similar to that of a brick.

Wilkeson Area.

Northern Pacific Railway Quarry.—The quarry of the N. P. Ry. Company is in Sec. 27, T. 19 N., R. 6 E. The quarry is about twenty-two miles east and ten miles south of Tacoma and is on a branch line of the N. P. that leaves the main line at Cascade Junction and terminates at Wilkeson. The hill in which the quarry is situated is about 1200 feet above sea level or 300 feet above the town of Wilkeson. At two other places in this district quarries have been operated in the past, but at present nothing is being done in either of them. They are each of them in the same formation as the present quarry and were abandoned principally on account of the fact that the stone was quarried by blasting, and the quarries were right in the town and the operation of them was dangerous, so the company went farther up the stream above the town and opened up a new quarry.

The stone from this quarry is a light colored coarse grained sandstone the cementing material of which is quartz. The stone here dips to the east at an angle of 60°. The face of the present quarry is 200 feet high and 100 feet long and contains three grades of stone. There is an upper and lower ledge having an average thickness of twenty feet each, which is good building stone, while the layer, which is twenty feet thick, between the two is not so good for building purposes. The N. P. did not get out building stone except for its own use. Some dimension stone is being quarried at the present time (Aug., 1901), but most of the stone shipped from here is for use along the road. The company is working fourteen men and shipping fifteen cars a month, which is a much smaller number than was being worked a year ago, when they were shipping 150 cars a month. These quarries have been leased at different times to private individuals and considerable building stone quarried.

Situated near here are a number of other deposits of good sandstone which are easy of access and well situated for easy quarrying.

An examination under the microscope of thin sections of the sandstone from this section shows it to be a little coarser

than that from the Cumberland area. There are in the N. P. quarry two layers suitable for building purposes which are very similar, except that the upper layer is a little coarser grained than the lower.

This sandstone consists of grains of quartz that have not been entirely rounded, some of them at least being quite angular. The cementing material is quartz and the grains are not held very firmly together by it. The rock contains some light colored mica disseminated through it in very small scales. There are also occasional grains of feldspar scattered through the mass. The grains of quartz are of quite a uniform size.

The following analysis shows the rock to be practically free from those substances that have a tendency to disintegrate rapidly and thus cause the stone to decay:

Silica ($Si\ O_2$)	98.05
Iron ($Fe_2\ O_3$)	0.89
Alumina ($Al_2\ O_3$)	0.07
Lime ($Ca\ O$)	0.22
Magnesia ($Mg\ O$)	0.12
Loss on ignition	0.76
	100.12

Samples of the sandstone from both the upper and lower ledges of the Wilkeson quarry were tested to determine the crushing strength, and, as shown in Table I., the following results were obtained: The samples from the upper layer had a crushing strength of 7,680 and 7,160 pounds to the square inch respectively, while those from the lower layer showed a crushing strength of 10,840 and 9,180 pounds to the square inch. The stone from the two layers has practically the same specific gravity, that from the upper one being 2.649, while that from the lower layer is 2.652.

The stone from the different layers was found to differ slightly in its ratio of absorption and porosity, as is shown in Table II., that from the upper layer having a ration of absorption of 4.13% and a pore space or porosity equal to 10.125% of its mass, while that from the lower layer has a ratio of absorption of 4.31% and a pore space or porosity equal to 10.027% of the mass of the stone.

The results of freezing and thawing tests made on samples of stone from the Wilkeson quarry are shown in Table III. Samples from both the upper and the lower layer were alternately frozen and thawed each day for a period of twenty days, and at the end of that time the loss in weight of the sample from the upper ledge was found to be .093 of 1% and that from the lower layer was .218 of 1% of the mass of the sample.

Samples were placed in a muffle furnace and gradually heated to a temperature of 800° F. and some of them cooled gradually, while others were cooled suddenly by being taken from the furnace and plunged into cold water and allowed to remain until cooled. The samples that were cooled suddenly crumbled on the corners and edges while those that were allowed to cool gradually were but little injured. Samples were then heated to 1,600° F., cooled gradually and while they did not crumble readily at the same time they were very much weakened and when struck with a hammer broke very easily. The color of all these samples from the Wilkeson quarry remained unchanged. This stone did not stand the sudden changes as well as the tufas did.

Fairfax Area.

Fairfax Quarry—Fairfax is six miles almost due south of Wilkeson. The quarry is in section 22, T. 18 N., R. 6 E. and is about one and one-half miles down the Carbon river from the coal mining camp of Fairfax. The quarry here is operated by the Fairfax Coal Company.

The sandstone quarried here is a light colored, fine grained and well cemented stone. It contains considerable muscovite and biotite and the stone is apparently quite free from iron.

The quarry at present is 110 feet long and has a face that would average 20 feet in height. The line of strike is N. 15° W. and dip 65° W. The stone quarried at present (July, 1901,) is being used by the Fairfax Coal Company for foundations for extensive coke ovens which they are building. I think no building stone has ever been quarried at this place.

This stone when first quarried is quite soft but hardens on being exposed to the atmosphere.

The microscopical examination of the sandstone from Fairfax shows that it is composed essentially of grains of quartz which as a general thing are clear and transparent and range in diameter from one-tenth of a millimeter to as much as one and one-tenth millimeters. There is in addition to the quartz grains quite a considerable amount of mica both the light and the dark colored in very small flakes disseminated through the stone. The cementing material is a light colored silica which holds the grains quite firmly together. Most of the grains are well worn and rounded. The stone has about the same color as the Wilkeson stone but has a little finer texture.

Stuart Island Area.

Stuart Island is one of the small islands in San Juan County and is about five miles north and two east of San Juan Island. The sandstones on this island have been quarried at three different places around Reed's Harbor. Two openings have been made on the north side of the harbor and considerable stone quarried, while a single small opening has been made on the south side. The stone varies very much in texture ranging from a fine grained sandstone up to a conglomerate in which the pebbles are as much as four inches in diameter. The color is dark and the stone is hard and well cemented.

The microscope shows the sandstone on Stuart Island to be composed essentially of medium sized to very coarse grains of quartz. The texture of the best stone from this locality is about the same as that of the Chuckanut stone, while the color is a little darker even than that of the Tenino stone. The cementing material is silica and iron. The individual grains of quartz are well rounded as a general thing in the stone from here. The stone from the south side of the harbor is harder than that from the north side.

As shown in Table I. this stone has a crushing strength of 8,900 pounds to the square inch. As shown in Table II. it

has a specific gravity of 2,724, a ratio of absorption of 1.82% and a pore space or porosity of 1.736% of its entire mass.

A sample was tested to show the effect of freezing and thawing by being alternately frozen and thawed for a period of twenty days and the loss in weight as shown in Table III. was .014 of 1% of the weight of the sample. A sample was placed in a muffle furnace and gradually heated to a temperature of 800° F. and cooled by being taken from the furnace while at this temperature and put into cold water. The sample was not cracked and so far as could be told was but slightly injured. Samples were then heated to temperatures of 1,200° F. and 1,600° F. and allowed to cool gradually. While these samples did not show any signs of cracks their strength was much less than before they were heated to these high temperatures. The color was changed to a light brick red.

Sucia Island Area.

Sucia Island is a small island, three miles due north of East Sound, in San Juan County. The sandstones occurring on this island have been quarried at two different places and considerable stone shipped from here. The stone is of a dark color, medium grained, and appears to be well cemented. The quarry was worked entirely by hand with the exception perhaps of a steam derrick or two for handling the stone. The stone from the quarry on this island was used in building the dry dock at Bremerton and as the stone had to be of exact sizes, to be accepted, there was a large amount of it rejected because it did not quite meet the requirements in dimensions and a large amount of good stone is still piled up in the quarry yard.

An examination under the microscope of a thin section of the sandstone from this locality shows that the grains of quartz composing it range in size from quite small, one-fifth of a millimeter in diameter, up to those that are as much as one millimeter in diameter. The larger part of the quartz grains are well rounded but occasionally one is found that has quite sharp corners.

The sandstone from Sucia Island is composed of clear

glassy grains of quartz together with quite a good many large dark colored flinty looking quartz grains and an occasional flake of black mica. These grains are held firmly together by a cement of silica which has somewhat of a greenish color. The color of the stone, however, is lighter than that of the Chuckanut or Tenino stone, and the green shows but very little.

The following chemical analysis shows this sandstone to have practically the same composition as the Chuckanut stone.

Silica ($Si\ O_2$)	90.21
Iron ($Fe_2\ O_3$)	3.64
Alumina ($Al_2\ O_3$)	1.98
Lime ($Ca\ O$)	0.72
Magnesia ($Mg\ O$)	0.81
Loss on ignition	2.42
	99.78

Samples of this stone were tested to determine ratio of absorption, percentage of pore space, and specific gravity and the results are shown in Table II. It has a specific gravity of 2.642, a sample weighing 59.757 grams absorbed 1.798 grams of water or 2.92 per cent. of its weight, and had a pore space or porosity of 7.364 per cent. of its entire mass. As shown in the same chapter, Table III., it lost in weight by being alternately frozen and thawed each day for a period of twenty days .18 grams on a sample weighing 59.737 grams, which is .058 of 1 per cent. of its weight.

Samples were heated to 800°, 1,200°, and 1,600° F. and some of them cooled suddenly, while others were cooled slowly. The samples at a temperature of 800° F. appeared to be but little affected, both those that were cooled suddenly and those that were cooled slowly. Those that were heated to higher temperatures, however, were much injured. On the surface they appeared sound but when tested they were found to break very readily and their strength was practically gone. The samples were changed in color so that they had a slightly reddish cast.

Conclusions.

The sandstones of Washington when compared with those being used for building purposes quarried in other parts of the

United States are found with one exception, that of the Chuckanut stone, to be below the average in crushing strength. As shown in Table II. the specific gravity is above the average, while the ratio of absorption is about an average. The percentage of pore space in some of the Washington sandstones is high but in most of them it is not excessive. The sandstones of this state withstand high temperaures well and in some cases are being used very successfully in place of fire brick.

CHAPTER V.

MARBLE AND SERPENTINE DEPOSITS OF WASHINGTON.

INTRODUCTION.

The term marble, in general, is used very loosely and is a commercial rather than a scientific term. By many it is made to include all limestones which will receive a polish, while by others only those limestones that are capable of being polished are suitable for ornamental purposes are considered as being marble.

Merrill * in speaking of marble gives the following: "Under the head of marbles there are here included all those rock consisting essentially of carbonate of lime (limestone) or carbonate of lime and magnesia (magnesian limestone and dolomite) that are susceptible of receiving a good polish and are suitable for ornamental work."

The term marble is also applied by some persons to ornamental stones which have a different mineralogical composition from the limestones. This, however, is not common.

Others again are inclined to restrict the use of the term marble to metamorphosed limestones. R. S. Tarr † has the following to say: "When a limestone has been metamorphosed, the carbonate of lime becomes altered to crystalline calcite, and the impurities gather together either in bands of different colors or in bunches of various minerals. This results in the formation of true marble, which should very properly be separated commercially from ordinary limestone, since it is metamorphosed and crystalline, and being capable of a high polish, serves for purposes for which ordinary limestone cannot be used. But under the term marble, in its commercial sense, is included many non-crystalline lime-

* Stones for Building and Decoration, pp. 83 and 84.
† Economic Geology of the U. S., p. 377.

stones, which by polishing, show either banding or some desired color, such as black. Consequently marble in its commercial significance is made to include stone which is not true marble."

There are many varieties of marble, the variation being principally in color and due in most cases to a variation in kind or amount of impurities, or both, which occur in it.

Marble is found in a number of places in Washington but the principal deposits are in Stevens county. Marble, however, is found in the Snoqualmie Pass region of the Cascade mountains and to the north of there in some few places. The amount, however, so far as known is not very great. In Stevens county the deposits are quite numerous and in many cases very large. At the present time western Washington is not producing any marble and but very little is known to occur in that part of the state.

METAMORPHISM.

Metamorphism is the process by which certain rocks have been changed from their original condition or the condition under which they existed when first formed. This change may result in the formation of new minerals, a change in texture, or simply a rearrangement of the minerals. Prestwich * defines metamorphism as follows:

Metamorphism is the molecular and structural change in the strata of the sedimentary series, or in the rocks of igneous origin, whereby they have undergone a transformation in the chemical combination of their elements, in mineral constituents, and in structure so that their original condition has been more or less modified and altered, and their characters disguised."

While in a certain sense this might include almost all sedimentary rocks as but few have retained their original condition, except having been hardened or having the grains cemented together, the term is, however, used only to include those greater chemical and mineral changes which have been

* Geology, Chemical, Physical and Stratigraphical, Vol. I, p. 397.

brought about by the combined action of heat, moisture and pressure. *

Metamorphism is of two kinds, as regards the area affected, as follows: Local or contact metamorphism and regional metamorphism. Local metamorphism as the term implies has not affected any very large areas and is usually found where igneous rocks in the form of dykes have been forced up into the sedimentary rocks such as sandstones and limestones and changed them to quartzite and marble. The conditions under which this eruptive material has been forced into these other rocks have varied more or less in different localities and on this account the metamorphism has varied, in some cases the change being but very slight and extending only a short distance from the eruptive material, while in other cases the change has been very great and widespread extending for considerable distances on either side of the eruptive mass.

If strata which have been invaded by igneous rock should be examined carefully we would find the metamorphism growing less and less as we went away from the contact until finally it would cease entirely, and if the strata should be limestone near the contact we might find crystalline marbles and as we went away from the contact there would be less and less change until the marble would finally grade into ordinary limestone.

Regional metamorphism affects much larger areas than does local and implies the changing and reconstructing of rock for very large areas, sometimes thousands of square miles, even, being affected. Such widespread changes could hardly be produced by the same causes that produced local metamorphism and consequently others must have been present also. The first step in metamorphism is probably a hardening of the strata and this may be due to either of the two agencies which Scott † designates as compression and pressure or by both of them acting together.

Different theories have been advanced at different times to account for metamorphism, but at the present time it is

* Ibid. p. 397.

† Introduction to Geology, p. 301.

pretty generally admitted that heat, moisture and pressure have been very important factors in bringing about the change that has occurred to produce these metamorphic rocks.

The reason for believing that heat has been an important factor in regional metamorphism is the fact that the results are very similar to local metamorphism. Then again many successful attempts have been made to imitate metamorphism experimentally and in all of these heat has been used. It is, however, not probable that in all cases very high temperatures were necessary to produce metamorphism. This heat has been accounted for in different ways by different persons. Dana * in discussing this subject gives the following:

"Regional metamorphic rocks are upturned rocks subjected to the faulting, crushing, and flexing attending mountain-making. Hence they are rocks which have been subjected to pressure and movement on a vast scale, and thereby to heat just where it was needed for metamorphic work. Mountain-making movements might be so slow that the heat would become mostly dissipated instead of accumulating. But the rocks upturned were generally 10,000 to 30,000 feet thick or more, and great pressure and high temperatures should be expected from movements so vast over regions extending sometimes a thousand miles in length.

"The heat for metamorphism appealed to is heat of a dynamical source, and the conditions are those that will produce its maximum effects."

Pressure appears to have been necessary in order to produce certain results found in the metamorphic rocks. Limestones even at low temperatures under ordinary conditions lose their carbon dioxide. Under heavy rock pressure this loss would not take place as has been shown by experiments, it having been melted under pressure without decomposition.

Scott † attributes regional metamorphism largely to compression and says that "to it are due the structures of cleavage, fissility, and schistosity, as well as the reconstruction and crystallization of mineral particles. This is dynamic

* Manual of Geology, p. 322.

† An Introduction to Geology, p. 291.

metamorphism, but heat is probably a common accessory in this method of change also."

The rocks of the earth's crust contain more or less moisture which under high rock pressure would be retained and become a very important factor in metamorphism. It has been shown experimentally by different persons that water at 400° C. will reduce to a pasty condition nearly all ordinary rocks. Moreover the amount of water necessary to produce this result, Le Conte says, is not large—only five to ten per cent.* This being true the included water of sediments is sufficient.

Dana † in discussing the presence of moisture gives the following:

"All rocks are permeated by moisture, and this permeating moisture is sufficient for all metamorphic results. If 2.67 per cent., which is less than the average, the amount would correspond to two quarts of water for each cubic foot of rock. At one per cent. it would be one pound, and, therefore, one pint of water to 100 pounds or two-thirds of a cubic foot of rock; and, since a pint contains 29 cubic inches of water, this amount would afford, at the ordinary pressure, nearly 45 cubic feet of steam to the cubic foot of rock. There is no doubt, therefore, about enough moisture.

"The distribution of heat through rocks without moisture is impossible; for heat travels but a short way into dry rock. A thickness of two or three feet is sufficient to confine nearly all the heat of the hottest furnace, and will make it safe to walk over liquid lavas. But let the walls of the furnace be wet, and the heat will go through with a rush, for the water becomes steam."

While it would appear that all of the agencies named above are important factors in producing metamorphism it is probably true that, in many cases at least, some one of these agencies has been the predominating one and the others may have been absent almost entirely.

The marbles of Stevens county occur in a district where the rocks are mostly metamorphic rocks and where great dis-

* Elements of Geology, p. 231.
† Manual of Geology, pp. 311 and 312.

turbances have taken place. The marbles vary in texture from those that are very fine and compact to those that are quite coarse. The composition of these marbles, as shown by the analyses given in Table V., varies from an almost pure calcium carbonate to an almost pure magnesium carbonate with all grades between. Most of the Stevens county marbles contain more or less magnesia. With our present knowledge of these marbles it is not possible to throw very much light on their origin. So far no evidence has been found of dolomotization, or replacement of calcium carbonate by magnesium carbonate, and at present it is not possible, however, to say how these deposits of magnesium carbonate have been formed as there is not evidence, such as is usually given, to show that they have been deposited by chemical action.

The Stevens county marbles are the products of metamorphism which was probably due, mainly at least, to heat, moisture and pressure. The heat was probably due partly to the disturbance of the strata which produced the tilting and folding and partly to heat from the interior furnished by the igneous rocks that are found in places beneath the marbles. In places later deposits are found lying on the marbles and these would insure rock pressure and this would prevent the escape of the carbon dioxide.

USES OF MARBLE.

Marble, being a calcium carbonate the same as ordinary limestones, is subject to all the uses for which ordinary limestone is suitable and in addition has special uses of its own, the most important of these being for outside building, interior, decorative, and ornamental purposes, monuments, and tombstones.

Outside Building Purposes.—Marble is not so generally used for this purpose as granite, limestone, and sandstone. There are several reasons for this, the principal ones of which are cost and the fact that good marble is less widely distributed geographically than the granite, limestone, and sandstone. The demand, however, for marble for this purpose is slowly increasing and many of our leading cities, and especially those

situated near good marble quarries, have not only their public buildings, which are built in whole or in part of marble, but also many private buildings which are built of this material. This is especially true of such cities as Washington, Baltimore, Philadelphia, and New York on account of their nearness to good marble deposits.

The amount of marble quarried in the United States and sold for outside building purposes in 1896 was valued at $1,036,163,* while in 1901 the amount sold for the same purpose was valued at $1,236,023 † or an increase for the five years of $199.860.

Interior Decoration in Buildings.—Marble has been used for decorative purposes since very early in the history of civilization. The Romans used very extensively the Italian marble as well as that of other countries in decorating the palaces of ancient Greece and Rome. In the United States marble is used to a considerable extent at the present time for decorative purposes such as wainscoting, columns, tiles, staircases, mantels, fireplaces, and carved work of various kinds. Some of the colored marbles of Washington would furnish some very handsome material for this kind of work. Marble is being used very extensively for tiling and is a very superior material for this purpose. The floors in the corridors and halls of many public and private buildings are made of marble tiling. It is being used very extensively also in the larger cities to furnish the entrance to many of the prominent buildings, and in many cases it has taken the place of wood for wainscoting, for which purpose any of the different varieties may be used.

The amount of marble being used for interior decoration in the United States is gradually increasing and in the last four years the value of that produced for this purpose has almost doubled, having been $576,983 in 1897 while in 1901 it was $1,008,482, or an increase of $431,499.‡

Cemetery Work (monuments and tombstones).—Marble is still the principal stone that is being used for this purpose.

* Eighteenth Annual Report U. S. G. S., Part V. (continued), p. 975.
† Mineral Resources of the United States, 1901, U. S. G. S., p. 666.
‡ Mineral Resources of the United States, 1901, U. S. G. S., p. 669.

The amount of granite, however, that is being used for monumental purposes is constantly growing and in 1901 the amount produced for this purpose alone was valued at $1,467,557,* while the value of the marble produced in the United States for the same year and used for monuments and tombstones was valued at $1,948,892,† or $481,335 more than the granite.

The white and clouded gray and bluish marbles have been used much more extensively for this purpose than have the highly colored ones. On the other hand the more highly colored granites such as the Scotch granite have been used more extensively for monumental work than the light colored ones. This being the case there is no reason so far as I can see why the more highly colored marble should not come into more general use for this kind of work and especially the best grades of the colored marbles at any rate.

Minor Uses.—There are a number of minor uses to which marble is especially well adapted, such as counters, sideboards, soda fountains, table and wash stand tops. While any of the different grades of marble may be used for these purposes the whites and white clouded from Italy, Vermont and Georgia have in the past been used more than any other kind. This, however, has been changing somewhat in the past few years and more colored marble is being used for these purposes and some of the colored marbles of Washington will undoubtedly prove to be very fine material for this kind of work and in the near future should be used quite extensively.

A certain amount of marble is used for statuary purposes. This, however, is not large and most of that used in the United States is imported. Some statutary marble has been quarried in Vermont, but the amount is small. The supply of good statuary marble is not large and does not equal the demand.

Mr. Ruskin says "statuary marble is neither hard, brittle, flaky, nor splintery, but uniform and delicately—yet not ignobly—soft; soft enough to allow the sculptor to work it without force, and to trace on it the finest lines of finished form; yet hard enough not to betray the touch, or crumble beneath

* Mineral Resources of the United States, 1901, U. S. G. S., p. 653.
† Ibid. p. 666

the chisel. Furthermore the stone should have a pure white color free from flaws or imperfections of any kind.*

Marble Production in the United States.—The amount of marble produced in the United States for the year 1901 was valued at $4,965,699. The leading marble producing states are Vermont, which for the same period produced marble valued at $2,753,583 or more than half of the entire output, Georgia with a production valued at $936,549, and Tennessee with an output valued at $494,637.†

There are a number of other states that produce some marble, but the amount is small. Washington is given credit by the same authority for having produced in 1901 marble valued at $22,816.

STEVENS COUNTY.

Stevens county is situated in the extreme northeastern part of the state. It has an average length, north and south, of about 76 miles, and average breadth of about 50 miles, an area of about 3,800 square miles and is one of the largest counties of the state.

The surface features of Stevens county may be separated into two somewhat distinct topographical areas. The first of these would consist of the southern part of the county or of that part which drains south into the Spokane and Little Spokane rivers. This region is one of plateaus and low hills which as a general thing are timbered. This part of the county ranges in altitude from 1,200 feet at the bottom, of some of the deepest canyons, to 4,082 feet, the top of the highest peak, above sea level. The general average of this part of the country is probably about 2,600 feet. The streams are short and some of them have cut quite deep gorges while others have comparatively shallow ones.

The second one of these topographical regions is much larger than the first and includes all of that part of the county which is drained to the north by the Colville and Pend d'Oreille rivers into the Columbia river. It would also in-

* Arkansas Geological Survey, Annual Report, 1890, Vol. IV., p. 170.
† Mineral Resources of the United States, 1901, U. S. G. S., p. 665.

clude that part of the county which drains to the west directly into the Columbia. It contains several good sized valleys, the principal ones of which are the Colville and the Pend d'Oreille situated along the streams of the same names. These valleys are level tracts of land along the streams from a mile to as much as two or three miles in width. Along some of the lateral streams many little valleys occur also.

Between the Columbia river and the Colville river, with the exception of the narrow valleys along these streams, the country is rough and mountainous, in places reaching an altitude, above sea level, of more than 6,000 feet and the divide between these streams has an average altitude of more than 4,500 feet. To the east of the Colville valley and between it and the Pend d'Oreille valley is another mountain range, of which the highest point, Calispell peak, has an altitude of 6,905 feet above sea level, with the average height of the divide between 4,800 and 5,500. East of the Pend d'Oreille river the country is mountainous and rough with about the same altitude as that to the west.

All of these mountain ranges are well supplied with lateral streams which have found in many instances quite deep gorges. The mountains rise gradually from the valleys first being the foot hills which gradually merge into the mountains. Along the Columbia the bluffs rise more abruptly than they do along most of the streams. The mountain ranges extend in an almost due north and south direction across the county.

The country rocks through Stevens county are granite, quartzite, slate, marble, limestone and metamorphic rocks in general. In places the sedimentary deposits are steeply inclined, having been much disturbed. In many places the marbles are found in contact with the granites. The marbles show stratification in but few places, the metamorphism having been great enough in most instances to destroy all evidence of it. In many places the deposits have been badly broken by the disturbances which have produced the metamorphism. Fossils, if they ever did exist, have been destroyed throughout most of the district. So far I know of but one

place where they have been found and this is near Valley Brook, where the Washington Brick, Lime & Manufacturing Company are quarrying the limestone which occurs there and using it for the manufacture of lime. These fossils are very scarce even here, are poorly preserved, and as yet it has not been possible to do very much with them. They have the appearance, however, of being Palaeozoic corals.

To the north of Stevens county in British Columbia the same marble and limestone deposits are found and in some places they contain a few poorly preserved fossils which are thought perhaps to be of carboniferous age. The Stevens county marbles and limestones are probably of the same age as those to the north in British Columbia and if the latter should prove to be carboniferous the Stevens county deposits are also very likely carboniferous. The amount of evidence at hand, however, at present is not sufficient to warrant any definite conclusions.

The southern limit of the limestones of Stevens county in a general way is about 48° north latitude or a few miles to the north of this. The southern deposits occur in isolated masses, do not cover large areas, and are not so common as the other kinds of rock, such as quartzite, granite and other igneous rocks. As one goes north from here the limestones or marbles become more common and cover larger areas until finally in the extreme northern part of the county the limestone forms quite a large part of the country rock.

In the southern part of the area where marble is found it occurs low down either in the valleys or low foot hills while to the north it is found at a much greater altitude. The highest parts of the mountain ranges, however, even in the northern part of the county are not limestone but igneous and metamorphic rocks such as granite, slate and quartzite. On either side of the Colville valley from about Valley Brook to the northern end of the valley more or less marble and limestone is found in the foot hills and mountains which border it.

The indications are that the limestones and marble which are found in Stevens county are the remnants of what was at

one time a much larger deposit covering the country to the west as far as the Cascade mountains. At the time these deposits were forming this area must have been under water and these sediments accumulated, after which there was an elevation and the sedimentary deposits were folded more or less and in places at least badly broken. At the time this elevation took plaec the igneous rocks were forced up into the sedimentary rocks, the sedimentary rocks more or less metamorphosed, and thrown into anticlines and synclines. Erosion began then to cut down this area and has succeeded in removing a large part of the limestone from it and especially from the highest parts where erosion would naturally be the greatest. The evidence of folding is not very great and only in a few instances has any evidence been found. There is, however, plenty of evidence that there have been very marked disturbances and in many places the strata are tilted and steeply inclined.

In many places, especially in the northern part of the county, evidence is found which shows that at some time in the past this part of Washington was covered with glaciers. In places large masses of rock, which are unlike the rock on which they rest, are found, while in others the country rock shows very plainly the effects of ice on the polished surface and striations which are found.

The marble and serpentine deposits in this area occur both to the east and the west of Valley, which is a station on the Spokane Falls & Northern Railway fifty-eight miles north of Spokane. The deposits to the west of Valley are from five to twelve miles from the railroad, while those on the east are only about three miles from the railroad. All of these deposits, however, are easily accessible as fairly good wagon roads have been built to them. Some of the properties in this district have been located since 1894, but very little, if any, development work was done before 1898. Since that time considerable money has been expended in opening up some of these deposits and at the present time a large amount of work is being done.

ONE OF THE STONE GANGS, U. S. MARBLE COMPANY, VALLEY.

QUARRY OF THE U. S. MARBLE COMPANY, VALLEY, FROM WHICH THE "PURPLE ATHENIAN" IS TAKEN.

VALLEY AREA.

The U. S. Marble Co.—The property of this company is situated in a number of places in Stevens county but the only place where much development work has been done is at the quarry, twelve miles west and north from Valley. From the railroad the quarry is reached by a fairly good wagon road which has been built for a considerable part of the distance by the company. The altitude of Valley is 1670 feet above sea level and the altitude of the mill at the quarry as determined by aneroid is 3,570 feet above sea level. This gives an average grade of a little less than 3 per cent. for the twelve miles. The quarry is about 500 feet above the mill. The mountains around the quarry rise to a considerable distance above it, Greenway Mountain being 4,615 feet above sea level as given by aneroid. This property consists of a group of twenty-one claims, about 420 acres, situated on the south side of the above named mountain, all of which are in Secs. 8 and 9, T. 31 N., R. 39 E.

The principal deposits being worked by this company at this place are serpentine. They have, however, deposits of dark, almost black, coarsely crystalline marbles and also slates.

Quarrying of the serpentines that occur on Greenway Mountin is being carried on by this company in at least three different places. The quarry situated on the east side of the mountain and known as the Greenway quarry was the first one to be opened and the one on which the most work has been done. The serpentine at this place occurs as a wedge shaped mass with the broader part of the mass extending downward. It cuts across the mountain in a line 5° to the west of north and the sides of this mass have a dip of 80°.

Greenway Mountain is composed principally of slates and limestones which dip to the north at an angle of 45°, while the strike is N. 10° E. The slate is light gray in color and lies conformably on the dark magnesian limestone and the serpentine cuts through both. The material quarried here is of various shades of green with more or less white scattered through it and the company has designated three of the most

common colors as follows: Royal Washington, Landscape Green, and Athenian Green. This material is all quite soft and easily worked into almost any shape. The thickness of this wedge shaped mass where exposed on the quarry floor is 20 feet and the quarry face at the present time (July, 1901,) is 75 feet long and 30 feet high.

The stone is quarried by steam drills, a series of holes being drilled in the face of the quarry, along the desired direction, as deep as the size of the block to be taken out. These holes vary as regards distance apart, on account of variation in the material, but are usually about three inches from center to center. After these holes have been drilled the drill is replaced by a cutter bar and the space between these holes is cut out. After the blocks have been loosened in this way on three sides they are broken off on the fourth by means of wedges and then are hoisted by means of a steam derrick and carried out into the quarry yard. One trouble with this material has been the frequency of seams that have occurred in it and which have to a certain extent, at least, prevented the quarrying of large blocks. This trouble, however, has lessened somewhat with depth and will probably continue to diminish as greater depth is reached. Serpentines, while they may be soft, may at the same time resist weathering well.

About five or six hundred yards south of the Greenway quarry across a deep gulch the United States Marble Co. has recently opened up a new quarry from which an entirely different grade of serpentine is being quarried. It differs from the other in color and in being much harder. The material has been designated by the company as Canyon Green. This body of serpentine, like the other, seems to be an irregular mass, alongside of which is a dike of igneous material called by Mr. Greenway a diorite. This material appears to be freer from checks and seams than that from the Greenway quarry and appears very promising.

The company has also begun the opening up of a new quarry a short distance below their mill on material which is entirely different from that being taken out of either of the other quarries and they have designated this Purple Athenian.

This material is, if anything, a trifle harder than the Canyon Green. The company has not done very much work at this place as yet and it is hard to tell how it will show up as depth is obtained but the indications are that large blocks of very beautiful stone practically free from seams can be obtained.

The United States Marble Co. has not done nearly as much work on their marble deposits as they have on the serpentines; some work, however, has been done toward opening a quarry in this deposit and if there should be a demand for the material it could be easily produced. This marble appears massive rather than stratified and the deposit is quite large. It resists weathering well, as shown by that exposed on the surface. It is quite hard and not so easily worked as most marbles. The deposit is practically free from seams and blocks of almost any size can be quarried. This material varies somewhat in color, ranging from a light gray to a very dark, almost black.

This company has a large and well equipped plant for quarrying and working the serpentine and marble deposits and employs from sixty to eighty men continually. The company has, for quarrying the serpentine, three 3-inch and one 2½-inch Rand drills which are operated on quarrying bars and are driven by steam which is supplied from a 45 H. P. boiler. The drills will each drill on an average about eight feet an hour. For handling the large blocks after they are quarried the quarry is supplied with a ten-ton derrick, which is operated by steam.

The mill for sawing, polishing and working the stone is about one-half a mile from the Greenway quarry at the foot of the hill and the large blocks of serpentine are loaded onto heavy trucks and hauled down the hill to the mill. The mill is supplied with two gang saws of the latest pattern and having automatic feed. These saws have a stroke of twenty inches, are 7x13 and 7x14 feet, and blocks of stone 6x6x11 and 6x6x12 feet can be cut. There is a rubbing bed thirteen and one-half feet in diameter and three machines for polishing the stone; also one eight-foot lathe, one four-foot lathe, two small lathes for fancy work, and a polishing lathe. The

power for driving this machinery is supplied by an 80 H. P. boiler and a 40 and a 50 H. P. engine.

In addition to the machinery already mentioned the company has recently installed a very complete pneumatic tool plant which operates a series of chisels that vary in size from those a quarter of an inch wide, used for the finest carving, up to the immense chisels used for dressing the blocks of stone just as they come from the quarry.

The company has established a general merchandise store which supplies its own employes and in addition does considerable business with the nearby inhabitants. The camp, which consists of bunk houses, kitchen, office, barns, store building, etc., is situated on the mountain side, 210 feet above the mill.

Thin sections of the serpentine from the Greenway quarry when examined under the microscope show it to be very finely crystalline and of uniform texture. Thin sections when viewed in ordinary light are transparent. In polarized light, under crossed nicols, they show brilliant colors.

Thin sections of the limestone or marble from this locality when examined under the microscope show it to be made up of very large but quite uniform sized crystals which interlock in a very intricate manner. When viewed in ordinary light it has a dirty and somewhat clouded appearance. Some of the crystals show very plainly the rhombohedral cleavage so characteristic of calcite while in others it is almost absent. In polarized light it is shown to be practically free from all foreign substances and to be, mineralogically, a very pure limestone.

The following chemical analysis shows the composition of the serpentine from the Greenway quarry:

Silica ($Si\ O_2$)	15.30
Iron ($Fe_2\ O_3$)	3.32
Alumina ($Al_2\ O_3$)	3.00
Lime ($Ca\ O$)	None
Magnesia ($Mg\ O$)	52.89
Carbon dioxide ($C\ O_2$)	1.27
Water at 110° C. ($H_2\ O$)	None
Water above 110° C. ($H_2\ O$)	23.86
	99.64

The following chemical analysis shows the composition of the dark coarsely crystalline limestone from the United States Marble Company's quarry:

Silica ($Si O_2$)	5.79
Ferric iron ($Fe_2 O_3$)	0.85
Ferrous iron (Fe O)	None
Alumina ($Al_2 O_3$)	0.43
Lime (Ca O)	1.69
Magnesia (Mg O)	42.07
Carbon dioxide ($C O_2$)	47.23
Water above 110° and undetermined substances	1.94
	100.00

The above analysis of the serpentine from this locality shows that it is entirely too low in the amount of silica it contains to be a normal serpentine. After having the analysis carefully checked and the same result obtained the second time a sample was sent to Mr. F. W. Clarke, Chief Chemist of the U. S. Geological Survey, with a request for his opinion of it and he has kindly furnished the following.

A Pseudo-Serpentine from Stevens County, Washington.

The "Serpentine" varies a good deal in color, and a series of samples in the U. S. National Museum shows that the output of the locality is far from uniform. They range from a white carbonate, through various intermediate mixtures of the verde antique type, to material which appears to be ordinary serpentine. The latter, however, as shown by the serpentine under consideration, is distinctly laminated in structure, and exhibits a splintery fracture. An analysis by Mr. George Steiger gave the following results:

$Si O_2$	13.08
$Al_2 O_3$	1.63
$Fe_2 O_3$	1.25
Fe O	0.19
Mg O	56.44
Ca O	0.33
$H_2 O$ at 100°	0.85
$H_2 O$ above 100°	23.94
CO_2	2.03
	99.74

These figures at once suggest a probable admixture of brucite with the serpentinous material, and a microscopic ex-

amination by Mr. J. S. Diller tends to confirm this supposition.

According to Mr. Diller the specimen is mainly composed of three minerals, **a**, **b**, and **c**. The first two have nearly equal indices of refraction, but differ widely in birefringence. The mineral **a** is the most abundant. In transmitted light it is colorless, but between crossed nicols it exhibits brilliant colors. The mineral **b** is pale green, and intermingled with **a**. Its birefringence yields weak colors, quite characteristic of chlorite. In quantity it is less than one-fourth of **a**.

Mineral **c** is granular, in scattered grains and irregular groups with a high index of refraction and a birefringence which suggests a carbonate, but it does not effervesce with a dilute acid. It amounts to not more than 5 per cent. of the whole. Mineral **b** is certainly chlorite, and **a** may be brucite or possibly serpentine.

By applying Mr. Diller's observations to the analysis of the rock, the proximate composition of the latter may be deduced; although certain assumptions must be made. The carbonate present is probably hydromagnesite for that species is a frequent associate of brucite. The composition of the chlorite is unknown, but it may be interpreted as essentially clinochlore, and proportional to the ferric oxide and alumina. So much assumed, the analysis gives the following approximate results expressing the composition of the specimen:

Hydromagnesite	5.0
Chlorite	14.0
Serpentine	20.0
Brucite	60.0
Extraneous water	1.0
	100.0

In this, four minerals appear instead of three, but the microscopic examination did not attempt to discriminate between the brucite and the serpentine.

In order to obtain evidence confirmatory of the foregoing conclusions, a few experiments were made, tending towards fractional determinations. Upon digesting the powdered rock for two hours with cold, dilute nitric acid (ten per cent. by

volume), 1.32 per cent. of $Fe_2O_3 \pm Al_2O_3$ and 47.29 per cent. MgO went into solution. In a similar experiment with cold, 20 per cent. acetic acid, 0.69 Fe_2O_3—Al_2O_3 and 45.64 MgO were extracted. Brucite dissolves readily in acids of the indicated strength, but some chlorite was evidently attacked as well. I also found that ordinary serpentine was quite appreciably acted upon by weak acetic acid. These experiments then merely show that the rock contains a large amount of magnesium in a very easily soluble condition, the quantity equivalent to 60 per cent. of brucite being 41.4. The results are in harmony with the conclusions already reached, and helps to support them, although accurate fractional determination cannot be made. The rock is unusual in character, and if the sample examined is fairly characteristic of the entire deposit, the latter should be carefully studied in reference to its origin and its geological relations.

F. W. CLARKE,
Chief Chemist.

U. S. Geological Survey,
Washington, D. C.,
Jan. 21, 1903.

Samples of the black marble from the quarry of the United States Marble Co. have a crushing strength, as shown in Table I., of 27,800 and 31,710 pounds to the square inch, while the modulus of elasticity as shown in the same table was 11,045,000 and 11,813,000 pounds to the square inch respectively. This stone has a specific gravity of 2.908, a sample weighing 65.025 grams absorbed .09 grams of water or .14 of 1 per cent. of the entire weight of the sample, and the percentage of pore space is .401 of 1 per cent. of the mass of the stone.

Samples were tested to show the effect of freezing by being alternately frozen and thawed each day for a period of twenty days and at the end of this time the loss was found to be .007 of 1 per cent. of the weight of the sample. Samples were also placed in a moist atmosphere of CO_2 and allowed to remain for a period of twenty days, at the end of which time a sample weighing 65.02 grams was found to have lost .005 of a gram.

Tests were also made on this marble by placing samples in

a muffle furnace and heating to a temperature of 800° F. Some of the samples were cooled suddenly by being put into cold water while at this temperature and allowed to remain until cold, when they were tested and found to crumble on the edges. Those that cooled slowly were but little injured. Samples heated to a temperature of 1,200° F. were completely destroyed even when allowed to cool slowly.

All of the serpentines being quarried by the United States Marble Co. take a very high polish and are very easy to work after the stone is taken from the quarry. This material is not so easy to quarry, however, as some stone on account of the fact that it has no bedding planes and occurs on the face of a steep mountain. All of the material being taken out of the quarry first opened is very soft and while it is very easy to work and takes a high polish it is suitable for only certain kinds of work. This includes what has been named by the company Royal Washington, Landscape Green, and Athenian Green. All of these have more or less of a splintery fracture. The chemical analyses given in this report of the serpentine from this quarry are of a sample of the Royal Washington. The softness of this material makes it very easy to work into all kinds of shapes and all kinds of ornaments may be manufactured from it. Unfortunately in the past, in some cases at least, this material has been used in places for which it is not well suited. The principal use for which this material is suited is decorations.

The company is opening a couple of new quarries from which a different grade of material is being produced. From one of these the Canyon Green material is obtained, while from the other the Purple Athenian is derived. These are either of them very handsome materials, considerable harder than that obtained from the other quarry, and would be suitable for most of the interior work for which marble is used; such as wainscoting, counters in banks, mantels, cornices, capitols, friezes, etc. This appears to be a very promising material and it seems to me the only question to be determined in connection with it is the extent of it and perhaps also the size of the blocks that can be obtained.

The black marble which occurs in connection with these serpentines has a very high specific gravity and high crushing strength. It takes a very good polish but is quite hard and not easily worked. As shown by the accompanying chemical analysis this is almost a pure magnesian carbonate and has very much the same composition as magnesite but it differs from most magnesite in the fact that it is crystalline. This stone is too hard to work to be used very extensively for purposes where dressed stone is required, but it might be used as an ordinary building stone if some cheaper means of transportation could be had than hauling by teams for a distance of twelve miles to the railroad. It is a stone that should last well in buildings.

The North American Marble & Onyx Co.—The property of the North American Marble & Onyx Co. is situated in Sec. 19, T. 31 N., R. 39 E., Secs. 24 and 25, T. 31 N., R. 38 E., and Sec. 12, T. 31 N., R. 39 E. There are seven claims in this property, six of which are west and a little north of Valley, a distance of from eleven to twelve miles, while the other is almost due northwest of Valley, a distance of five and one-half miles and is very close to the property owned by the Washington State Marble Co. A wagon road has been built to these deposits and an average grade of 3 per cent. obtained.

This company has done but very little work on any of its claims. A few openings have been made on some of them but no systematic development work has been done. The altitude above sea level of the Green Gem, Malachite and Creole is 3,310 feet. Two openings have been made on these claims along the bluff and some very good looking material is exposed. These openings are about one hundred feet apart and the deposits are exposed for a distance of fifty feet in one place and sixty feet in another and the indications are that the deposits are practically the same between these two openings. These deposits outcrop at intervals for a distance of at least 200 feet above these openings and above that they are covered with soil and gravel. Between the deposits where the openings have been made, and the slates which lie over them, is a body of limestone which differs from the other somewhat.

This material seems to resist weathering well as shown by that exposed in these openings. It varies much in color, ranging from solid greens to those in which the greens and whites are intimately mixed.

One-half mile up the small creek from the above named claims are the Brooklyn, Greater New York and the Black Bear. These claims are 4,310 feet above sea level or 1,000 feet above the other claims. The deposits on these claims are in places somewhat stratified, while in others they are massive. In places small seams of quartz are found in these marbles. Seams and joints are quite common but not enough so but what good sized blocks could be quarried. One set of these joints is fairly regular, while the others are not. This material is quite hard and resists weathering well. Some work has been done on these claims but no very great depth reached at any place. The prevailing colors here are pink and various combinations of pink and white.

These claims are not so easy of access as the others owned by the same company. They are a little more than half a mile from the wagon road and it would be quite expensive to build a road to them as they are eight hundred to one thousand feet above where the road at present terminates. It would, however, be possible to build a road up the gulch to the foot of the mountain in which the deposits occur and there build a tramway up the mountain to the deposits. The outcrop of the red marble, which is found here, has been traced for a distance of 3,000 feet on either side of the deposit and it is known to have a width of from 600 to 1,000 feet with bluffs from 75 to 100 feet high.

A small stream of water passes through these claims and would furnish, at all times, enough for running an engine and a mill for cutting and working the marble.

The claim known as the Ophir Onyx, owned by this same company is not nearly so difficult of access as the others, being only about one-half mile from a good wagon road. It is 2,465 feet above sea level or 795 feet above the railroad at Valley. Several openings have been made on this claim and in one place a depth of thirty feet has been reached. These

deposits contain both marble and serpentine of various colors from green to pure white with various mixtures of green, white, pink and purple. The serpentine, in places, is very intimately associated with the marble, occurring in layers alternating with it; this, however, seems to be the case only near the surface and as depth is obtained the serpentine disappears entirely. In one opening that has been made the material at and near the surface is serpentine and a short distance below the surface thin layers of marble begin to appear in the serpentine and these keep gradually increasing in number and thickness as greater depth is obtained until they compose the whole of the deposit.

The marble on this claim is distinctly stratified and has a dip which varies somewhat in amount, being in places as much as 25°. The deposits are very little checked and broken even near the surface and large sized blocks could be quarried with very little depth; there is a good supply of the material and it resists weathering well, as shown by the exposures in the bluffs and it lies in a position quite favorable for easy quarrying.

Thin sections from these deposits, examined under the microscope, shows that the deposits vary from very fine grained to those that are very coarse grained. Thin sections of the coarse grained pink colored limestone are fairly uniform as regards the size of the individual crystals. When viewed in ordinary light the sections appear somewhat clouded with one set of parallel lines well marked. In a few of the crystals the rhombohedral cleavage so characteristic of calcite is very marked. The crystals interlock in a very complex way and this accounts quite largely for the very great strength of this stone. Under polarized light the stone is seen to have a very simple mineralogical composition, being composed principally of magnesium carbonate or magnesite. The twinning so common in calcite is absent here.

Sections of the finer grained stone present an entirely different appearance from the above described ones. In ordinary light they have a clouded and slightly yellowish tinge. The principal mineral is dolomite with some serpentine. In places

in some of the sections the serpentine shows a very distinct mesh structure, while many of the calcite crystals show very plainly the characteristic rhombohedral cleavage. In polarized light under crossed nicols twinning is shown to be quite common.

Thin sections of the serpentine from these properties viewed in ordinary light are clear and transparent in places, while in other places they are very much clouded.

The following analysis shows the chemical composition of the coarse grained pinkish colored material from the property of the North American Marble & Onyx Co.:

Silica ($Si O_2$)	0.89
Ferric iron ($Fe_2 O_3$)	0.00
Ferrous iron ($Fe O$)	0.58
Alumina ($Al_2 O_3$)	None
Lime ($Ca O$)	None
Magnesia ($Mg O$)	45.76
Carbon dioxide ($C O_2$)	49.24
Water above 110° and undetermined sustances ($H_2 O$)	3.53
	100.0

Below is given an analysis of a sample of the very fine grained light colored stone from the Ophir Onyx claim of this company:

Silica ($Si O_2$)	40.35
Ferric iron ($Fe_2 O_3$)	0.00
Ferrous iron ($Fe O$)	1.66
Alumina ($Al_2 O_3$)	None
Lime ($Ca O$)	11.85
Magnesia ($Mg O$)	22.07
Carbon dioxide ($C O_2$)	17.32
Water above 110° and undetermined substances ($H_2 O$)	6.85
	100.00

The chemical composition of the serpentine from this property is shown by the following analysis:

Silica ($Si O_2$)	38.47
Ferric iron ($Fe_2 O_3$)	2.04
Ferrous iron ($Fe O$)	0.00
Alumina ($Al_2 O_3$)	0.16
Magnesia ($Mg O$)	38,86
Lime ($Ca O$)	None
Carbon dioxide ($C O_2$)	4.84
Water above 110° and undetermined substances ($H_2 O$)	4.63
	100.00

From the above analysis it is seen that there is a wide variation in chemical composition in the material found in the deposits owned by this company. The coarse grained pink is a magnesium carbonate entirely free from calcium carbonate, while the fine grained is a mixture of magnesium carbonate, calcium carbonate and magnesium silicate. In some cases the magnesium silicate is in the form of serpentine, while in others it is more or less in the nature of talc. The samples analyzed were taken as extremes and much of the material would have less silica and magnesia and more calcium carbonate.

Samples of the pink colored magnesium carbonate from the property of the North American Marble & Onyx Co. were found to have a specific gravity, as shown in Table II. of 2.858. A sample weighing 48.02 grams absorbed .052 of a gram of water or .18 of 1 per cent. of its entire weight. It had a pore space or porosity of .308 of 1 per cent. of its mass.

Tests were made to determine the effect of freezing and thawing on the weight of samples of this stone by alternately freezing and thawing them each day for a period of twenty days, at the end of which time it was found that the loss as shown in Table III. was .014 of 1 per cent. of the weight of the samples tested. It was also tested to see what the effect on it would be of a moist atmosphere containing Co_2 and at the end of twenty days a sample which weighed to begin with 48.013 grams had lost .003 of a gram.

Samples were placed in a muffle furnace and heated to a temperature of 800° F. and taken from the furnace and put into cold water while at this temperature and allowed to remain until cooled, when they were carefully examined and so far as could be told they were uninjured. Samples were then heated to 1,200° F. and allowed to cool gradually and were found to be practically ruined, being calcined throughout the larger part of the sample and after being left out in the air for a few days the samples crumbled and fell to pieces.

The pink colored coarsely crystalline magnesium carbonates from the property of the North American Marble & Onyx Co. is almost identical in texture and composition with the

black marble from the quarry of the U. S. Marble Co. The hardness is practically the same and in fact the only respect in which it differs from the other is in color. The color is a pink or red and is fairly uniform. In places there are seams of white mixed with the red. This stone takes a very good polish but on account of its hardness is not as easily worked as ordinary marbles and consequently more expensive. It would be a very handsome stone for building purposes, for which it is undoubtedly well suited on account of its strength, color and ability to resist weathering well.

The material occurring in the Green Gem, Malachite, and Creole claims, which has usually been considered as serpentine, is found to be a mixture of calcium and magnesium carbonate with serpentine in varying amounts. The material, however, takes a good polish and is hard enough so that it would be suitable for all kinds of interior finishing and decorative work, while on the other hand it is not so hard as to make it difficult to work.

On the Ophir Onyx claim still a different kind of material is found. It varies much in composition, ranging from a true serpentine to crystalline magnesium carbonates with only small amounts of calcium carbonate. The material takes a good polish and except in the case of that containing a high percentage of silica it is not difficult to work. This claim is the best situated of any of the claims owned by this company, being much nearer the railroad and only a very short distance from a good wagon road. The finest grades of decorative stone will bring a high enough price so that it is possible to transport them for some distance by teams but ordinary grades of building stone as a general thing will not stand this heavy expense. The question of transportation is a very important one in connection with the working of the deposits owned by this company and one that should be very carefully considered.

Washington State Marble Co.—The deposits owned by the Washington State Marble Co. are in Secs. 6 and 7, T. 31 N., R. 40 E., and Sec. 12, T. 31 N., R. 39 E. The company has 80 acres in Sec. 6, 160 acres in Sec. 7, and 120 acres in Sec. 12, making in all 360 acres. In addition to this the company has

40 acres of deeded land a short distance north of the north line of the above located property which includes a water power right and mill site on Huckleberry Creek. This property is distant five miles northwest from the Spokane Falls and Northern Railroad, a branch of the Great Northern system, at Valley.

The property of this company is easily accessible, there being a good wagon road most of the way to it and with a very little work it could be put in good condition the rest of the way. The deposits as given by aneroid are, at the cabin, 2,500 feet above sea level or 830 feet above Valley. Taking the distance as 5½ miles and we would have an average grade of about 3 per cent. From Wait's Lake to the property is one and a half miles and the difference in altitude is 500 feet and for this distance the average grade would be about 6 per cent. The altitude of the marble deposits at their highest points on this property is 3,000 feet above sea level and in places there are almost perpendicular bluffs of marble from 300 to 500 feet high.

But very little work has been done on this property up to the present time (July, 1902,) only a few very small openings having been made. The marble on this property is somewhat broken on the surface but will probably improve as depth is obtained. Some fairly good sized blocks for surface material have been quarried. From all indications this marble will resist weathering quite well. The amount of marble exposed here is very large and practically inexhaustible. The deposits are more or less bedded and vary in the amount of dip from 10° to 30° and the direction of dip is toward the west. The bedding planes vary much as regards their distance apart, in some places being not more than a foot or two, while in others they are as much as fifteen to twenty feet. The stream on the property even at its lowest stage could probably be made to produce from one hundred and fifty to one hundred and seventy-five horse power, which would be sufficient to operate a large plant. These deposits vary much in color as well as in composition, the prevailing colors, however, are

some shade of pink or green with various combinations of this and in some cases there is a distinct purple tinge.

Thin sections of this material viewed under the microscope show it to vary much in structure, being in some cases very fine grained, while in others it is quite coarse grained. There are also all grades between these extremes. Viewed in ordinary light the sections have a dirty appearance and are shown to be made up of grains that are quite uniform in size with the exception of those found in small veins which traverse the material taken from certain places in these deposits. The grains in the individual sections, however, vary much in size. In places these deposits contain a considerable amount of serpentine while in others they are practically free from it.

The following chemical analysis show the composition of a sample of the pink and of the green material from these deposits:

	Pink.	Green.
Silica (SiO_2)	18.18	10.47
Ferric iron (Fe_2O_3)	0.45	0.56
Ferrous Iron (FeO)	1.17	0.57
Alumina (Al_2O_3)	0.44	1.85
Lime (CaO)	24.74	32.66
Magnesia (MgO)	16.10	15.03
Carbon dioxide (CO_2)	38.18	38.19
Water at 110° C. (H_2O)	0.05	0.10
Water above 110° C. (H_2O)	0.69	0.57
	100.00	100.00

The above analysis shows that both the pink and green material from these deposits contains quite a considerable amount of silica which is probably combined with the magnesia to form a serpentine.

A sample of the pink colored marble from the deposits owned by the Washington State Marble Co. was found, as shown in Table II., to have a specific gravity of 2.829. As shown by the same table a sample weighing 93.309 grams absorbed 1.225 grams of water, which was 1.32 per cent. of the weight of the sample. It had a pore space or porosity of 3.578 per cent. of the mass of the sample.

These deposits have some very handsome colored marbles which take a very high polish. The material is a trifle harder

than ordinary marbles but at the same time it is not so hard as to make it difficult to work. It has a high specific gravity, being considerable above the average for marbles and limestones. The deposits are easier of access than many of the Stevens Co. marble deposits and are fairly well situated for being worked economically.

Pacific Coast Marble, Tiling & Manufacturing Co.—This company owns property located in Sec. 18, T. 31 N., R. 41 E. The quarry and mill are about two miles almost due east of Valley, but to follow the wagon road it is four miles to the quarry. The altitude of the quarry above sea level as given by single reading of the aneroid is 2,150 feet or 480 feet above the railroad at Valley. The property is easy of access, having a good wagon road all the way from Valley to it. The company owns about forty acres of land, all of which has been taken for marble.

Considerable work has been done by this company and a fair start made toward opening up a quarry. A depth of forty feet has been reached and some large blocks which appear to be quite free from seams have been taken out. These deposits are massive and in no place, so far as I could see, do they show any sign of stratification. They extend north and south for a distance of about four miles, and in Sec. 18 have a width of about one-third of a mile. In this distance of four miles, however, the material varies a great deal and much of it is of no value. There have been several openings made at different places on this property and the fact of an extensive deposit existing here proven.

Near the surface the deposits are considerably broken and quite a good many seams are found running through them but they improve with depth, as is shown in the quarry at the present time when a depth of only forty feet has been reached. The material varies considerably in color, that at or near the surface being different from that some distance below the surface. The surface material is a mixture of white, green and occasionally a very little red in various shades and markings, while below the surface a short distance the prevailing colors are sienna, white and green, with some very dark brown.

The sienna forms the main part of the stone and the other colors show through it in streaks and seams and produce various markings and a very pleasing effect. To the east of this property are limestones and quartzites, the ridges being quartzite and the limestone lies on it but does not reach so great an altitude as the quartzite does. West of the property about one-half a mile slates outcrop. There is a nice spring of water on the property which will probably supply enough for the operating of the mill and engine.

The company has a small plant on the property consisting of an automatic feed gang saw 6x12 feet, a rubbing bed six feet in diameter, one polisher, and two steam drills complete for use in the quarry. The power for driving this machinery is furnished by a 40 H. P. boiler and a 25 H. P. engine. The mill is about 100 feet long by 35 feet wide. In addition to the above there are such otner things as derrick, blacksmith shop and cook house.

Thin sections of the material from the property of this company examined under the microscope show it to have a very fine and even texture with frequently fine veins of calcite occurring in it. In ordinary light the sections present a very clouded and dirty appearance. The fine seams are quite common in places in the sections and they appear to have been formed after the main mass of the stone. The principal mineral is calcite, which in a very few instances shows the characteristic rhombohedral cleavage.

The following analysis shows the chemical composition of a surface sample and one entirely free from the brown or sienna colored material:

Silica ($Si O_2$)	27.11
Ferric iron ($Fe_2 O_3$)	1.90
Ferrous iron ($Fe O$)	2.44
Alumina ($Al_2 O_3$)	1.90
Lime ($Ca O$)	23.68
Magnesia ($Mg O$)	15.45
Carbon dioxide ($C O_2$)	19.30
Water and undetermined substances	8.32
	100.00

The above analysis, when considered in connection with the general appearance of the stone, would tend to show that

calcium carbonate and serpentine are the principal minerals in this material, with small amount of silica, iron, alumina and other substances occurring as accessory minerals.

This material is not a building material and should be used only for decorative purposes. It is of medium hardness but not hard enough to make it difficult to work. It takes a very fine polish and some very handsome colors occur in the deposits. The nearness of this deposit to transportation and the ease with which it can be reached are points in favor of producing it cheaply, while on the other hand the conditions in connection with quarrying the stone are such that the quarry will be a little more expensive to work than the average quarry. The important question here, as it is in many of the Stevens county marbles is the one as regards the size of the blocks that can be obtained with depth.

The Green Mountain Marble Co.—In Sec. 13, T. 31 N., R. 40 E. is the property owned by what is known as the Green Mountain Marble Co. This property is about one and one-half miles almost due east of Valley and very easy of access as it is close to a good wagon road. The deposit has been opened up in one place and some development work done. It is principally of a green color with various markings and is very handsome. It has a very fine texture, contains calcium carbonate and magnesium silicate and is probably a mixture of marble and serpentine. In the opening which has been made are exposed chlorite schists, talc and the above described material. A depth of about twelve to fifteen feet has been reached in this opening. The material takes a good polish and is hard enough to hold it well. The principal trouble with this deposit is the fact that it is very badly broken and at the time I visited the property (July, 1902,) it was not possible to obtain anything like large pieces without they were full of seams and cracks; this, however, may change when a greater depth is reached. The indications, however, on the whole are not very favorable for this material, being entirely free from checks and becoming entirely sound until considerable depth is obtained, if it does even then.

MILAN AREA.

The Spokane Marble Co.—The property of this company is six miles north and a little west from Milan, which is a small station on the main line of the Great Northern Railway, twenty-six miles north and a little east of Spokane, and is in Sec. 32, T. 30 N., R. 43 E. It is on what is known as the west branch of the Little Spokane river and has an altitude of 2,050 feet above sea level, or 271 feet above Milan, which gives an average grade of a little less than 1 per cent. for the six miles. The wagon road as located at present, however, reaches a greater altitude than this before the quarry is reached and comes down to it but at the same time the road has a very easy grade and the property is easy of access.

The company has 160 acres of deeded land and three claims of 20 acres each, located under the placer act, making 220 acres in all.

The Spokane Marble Co. has done quite a large amount of work toward opening up and developing their property and at the present time have an almost perpendicular face exposed for a horlizontal distance of about 50 feet and 30 feet vertically. The marble found here is of various colors, from black to a very light, slightly yellowish gray, with various mixtures of black, white and green. The mixtures of the black, white and green are probably the best grades of stone found in these deposits. These deposits are massive where they have been exposed and in no place did I see any signs of stratification.

The indications are that this marble will resist weathering well and that the deposits are quite extensive. The extent is not, however, definitely determined as yet as the surface material throughout this locality is a mixture of soil and gravel which covers and hides the country rock in most places. A few small openings, however, have been made at different places on this property and the same character of material found in each case. This material is not so badly broken and has less seams and checks in it than many of the Stevens county marble deposits and fair sized blocks of very handsome

stone can be taken out even with the present development of the quarry. The property is well supplied with water, timber and sand for the mill.

The company has a small plant for working the quarry, cutting and polishing the marble. A small mill has been built and in this a gang saw 8 feet long, a rubbing bed 3 feet in diameter, a large lathe, and tools for marble turning, and a Rand air compressor have been installed. The power for driving this machinery is water, which is supplied by a ditch and pipe 1,200 feet long, and a Pelton wheel. The water is from a small stream running through the property and this stream is fed by a very large spring. This water has 150 feet fall and develops 45 H. P.

A short distance southwest from the mill some white marble occurs and one or two openings have been made but no work to speak of has been done. The surface indications here are not very favorable as the marble is badly broken and contains more or less iron sulphide scattered through it which would injure it even if it were not so badly broken as to make it of no value. The country rock through this locality is granite principally, with some quartzite and shale with the marble occurring in places.

Thin sections of the marble from the property of the Spokane Marble Company examined under the microscope show it to be composed essentially of calcium carbonate and serpentine with some magnetite and more or less clayey material scattered through it. In ordinary light the calcium carbonate has a clouded appearance and in places shows very plainly the rhombohedral cleavage. The serpentine when viewed in ordinary light is transparent and almost clear. When viewed in polarized light, under crossed nicols the calcite shows polysynthetic twinning so characteristic of it and the mesh structure of the serpentine is very distinctly shown.

The following analysis shows the chemical composition of the material from the quarry of the Spokane Marble Co. The silica and magnesia are combined and with water form the serpentine. The carbon dioxide and lime are united to form

the calcite, which is common throughout the rock, while the iron is probably an oxide, principally at any rate, with perhaps a little sulphide and the alumina and some of the silica have combined to form a small amount of clay:

Silica ($Si\ O_2$)	27.93
Ferric iron ($Fe_2\ O_3$)	2.08
Ferrous iron ($Fe\ O$)	2.38
Alumina ($Al_2\ O_3$)	2.32
Lime ($Ca\ O$)	13.05
Magnesia ($Mg\ O$)	27.74
Carbon dioxide ($C\ O_2$)	11.33
Water and undetermined substances	13.17
	100.00

Cubes of the stone from the property of the Spokane Marble Co. were tested to determine the crushing strength and the results are shown in Table I. Samples of the dark colored marble from this quarry were found to have a crushing strength ranging from 8,210 to 10,400 pounds to the square inch and a modulus of elasticity of from 3,309,000 to 4,208,000 pounds to the square inch. Samples of the light yellow material from the same property had a crushing strength of from 12,180 to 14,820 pounds to the square inch with a modulus of elasticity of from 3,876,000 to 11,023,000 pounds to the square inch.

Tests were also made to determine the ratio of absorption and as shown in Table II. a sample weighing 46.729 grams absorbed .154 of one gram of water or .33 of one per cent. of the weight of the sample and had a porosity or pore space of .881 of 1 per cent. of its mass. It has a specific gravity of 2.696. A sample was alternately frozen and thawed each day for a period of twenty days, at the end of which time it was found that the sample had lost .019 of 1 per cent. of its weight.

The effect of CO_2 in a moist atmosphere was tested and at the end of a period of twenty days it was found that a sample weighing 46.64 grams had lost in weight .002 of a gram. Samples were placed in a muffle furnace and gradually heated to a temperature of 800° F. Some of the samples were taken from the furnace and put into cold water, while at this temperature, and allowed to remain until cooled, while the others

were allowed to cool slowly. The samples that were cooled suddenly were cracked and practically destroyed, while those that were allowed to cool slowly were but little injured. Samples heated to a temperature of 1,200° F. were calcined and crumbled to pieces.

This marble is easy to work and takes a good polish. These deposits are well situated for being worked cheaply as the company has a very fine water power for running all the machinery, such as saws, polishers, lathes, rubbing bed and the drills used in the quarry. This is a very handsome ornamental and decorative material and will probably never be used very extensively, if at all, as dimension stone for ordinary building purposes. The stone has a crushing strength above the average for marbles as shown in Table I., while the specific gravity is about the average and the ratio of absorption below the average.

Colville Area.

Colville, the county seat of Stevens county, is eighty-nine miles north and a little west from Spokane and is on the Spokane Falls and Northern Railway. The marbles of this area are northeast and southwest from the town a distance of from six to twenty miles. Some of these deposits have been located for a number of years but it is only within the last year or two that anything like active development work has been carried on. Most all of these properties are easy of access and fairly good wagon roads have been built to them.

The Jefferson Marble, Mining & Milling Co.—The quarry of the Jefferson Marble Co. is northeast from Colville, by wagon road, a distance of fifteen miles. The property is situated between the north and south forks of Clugston creek and consists of twenty-two claims of 440 acres, together with the exclusive water right on Clugston creek, which passes through the property. The quarry is reached by a fairly good wagon road, for a mountain road, which has been constructed to it and which has a moderate grade for all except the last three-fourths of a mile before the quarry is reached and this is quite steep.

These deposits cover a large area here and are practically inexhaustible, at any rate for years to come. They show stratification in places while in others they appear massive. The atmospheric agencies seem to have little effect on this material, at least so far as can be told from field exposures. This material varies a great deal in color and it is stated by the company that they have twelve distinct colors varying from dark blue to pure statuary white, but their most promising material is probably their variegated or mottled brown and white. This is a very handsome stone and should prove a very valuable stone, especially for decorative purposes. The marbles in this locality vary somewhat in hardness, as is shown by the way in which it has weathered. The property is well supplied with water, timber and sand.

On the surface these deposits are quite badly broken and as yet very little depth has been reached in any place, so that it is hard to say what the condition will be below the surface. The deposits are fairly well situated in places at least for economic quarrying and with a channeler blocks 4x4x6 feet are being taken out and while they have some checks in them they are quite good for surface material. Where the deposits show stratification, however, they are steeply inclined, the angle of dip being from 60° to 80°.

The company has installed quite a complete plant for quarrying and working marble. The quarry is equipped with one of the latest improved Wardwell four-foot channeling machines, by means of which blocks are cut out on four sides and then broken loose on the lower side by means of wedges. In addition to the channeling machine the quarry is supplied with a large derrick, which is operated by steam, for handling the marble. The company has steam drills and all the minor apparatus needed for operating the quarry.

A good sized mill has been built and a 6x14 foot gang saw for sawing the marble has been installed; also a 9-foot rubbing bed, and an engine and boiler for driving the machinery. The company have their own saw mill and cut their own lumber, quite a large amount of which they have used in the construc-

tion of buildings for the accommodation of the men employed in operating the property.

Thin sections of the marble from the Jefferson quarries, when viewed under the microscope, show that this material varies considerably in texture, in some cases the individual grains or crystals being very regular in size, while in others they vary a great deal, ranging from those that are less than 1-20 of a millimeter to those that are as much as a millimeter in diameter. This material, however, taken as a whole, is very fine grained. The crystals or individual particles in this marble are very closely interwoven and have only very small spaces between them. When viewed in ordinary light these marbles have a slightly clouded appearance. In some few cases rhombohedral cleavage is quite marked but on the whole it is not very common. The microscope shows this material to be entirely crystalline and when viewed in polarized light twinning is seen to be very common.

The following chemical analyses of samples, from the Jefferson quarry, of the pure white marble and the variety having a slight pinkish cast show these deposits to be very pure calcium carbonate practically free from magnesia, iron and alumina. The sample having the pinkish cast is seen to have more silica than the other and a little iron which is probably the cause of its color:

	White.	Pinkish.
Silica ($Si\ O_2$)	0.87	3.49
Iron ($Fe_2\ O_3$)	None	0.24
Alumina ($Al_2\ O_3$)	None	None
Lime ($Ca\ O$)	55.16	51.54
Magnesia ($Mg\ O$)	0.21	1.11
Carbon dioxide ($C\ O_2$)	43.77	42.46
Water at 110° C. ($H_2\ O$) and undetermined substances	None	0.16
	100.01	100.00

Tests were made on three of the different grades of the marble found in these deposits and as shown in Table II. the fine grained pure white had a specific gravity of 2.719, a ratio of absorption of .35 of 1 per cent. of its weight, and a pore space or porosity of .957 of 1 per cent. of the mass of the sam-

ple. The dark blue marble has a specific gravity of 2.594, a ratio of absorption of .07 of 1 per cent. of its weight, and a porosity of .184 of 1 per cent. of the mass of the stone. A sample of the white and brown, mixed, had a specific gravity of 2.72, a ratio of absorption of .12 of 1 per cent. of its weight and a pore space or porosity of .341 of 1 per cent. of the mass of the space or porosity of .341 of 1 per cent. of the mass of the sample.

Tests were made on the same grade of marble to show the loss in weight by freezing and thawing and the results are shown in Table III. After being alternately frozen and thawed each day for a period of twenty days it was found that the pure white had lost .066 of 1 per cent. of its weight, the dark blue .05 of 1 per cent. of its weight, and the white with brown had lost .042 of 1 per cent. of the weight of the sample. The white was tested to determine the effect of CO_2 in a moist atmosphere and at the end of twenty days a sample weighing 45.27 grams had lost in weight .004 of a gram.

Samples were placed in a muffle furnace and gradually heated to a temperature of 800° F. Some of the samples were cooled quickly by being taken from the furnace while at the above temperature and put into cold water and allowed to remain until cooled, while others were allowed to cool more gradually and in both cases the samples were uninjured so far as could be told. At 1,200° F. the samples were calcined and when cold crumbled to pieces.

This marble takes a good polish and is easy to work. The deposits, in places at least, are quite steeply inclined and considerably broken on the surface. Some very fine grained and quite clear white is found here. The most promising material, however, so far found in these deposits is probably the mixture of the white and yellowish material. This is a very handsome stone and would be well suited for all kinds of ornamental work. At the time I visited the property last the work had just been commenced on this last named material and the material being taken out was right from the surface and it had quite a good many checks and seams in it. All of the material from here will have to be transported, at the present time at

CHANNELER IN THE QUARRY OF THE JEFFERSON MARBLE, MINING AND MILLING COMPANY, COLVILLE.

QUARRY OF THE CRYSTAL MARBLE COMPANY, COLVILLE.

least, by teams for a distance of fifteen miles, which is an important item affecting the cost of this marble.

Crystal Marble Co.—The marble deposits owned by the Crystal Marble Company are situated about seven miles southwest of Colville on the right hand bank of Stensgar creek and are in Secs. 26, 27, 34 and 35, T. 34 N., R. 38 E. The company has located 1,320 acres of land in this locality for marble. At the present time the property is reached by a wagon road either from Colville or Addy, but it is the intention to build a road to the property, starting at Winslow, which is a small station on the S. F. and N. R. R. between Addy and Colville, and in this way the distance will be much shortened. The altitude of these deposits, as given by aneroid, where the company is getting ready to quarry them, is 2,400 feet above sea level, or 798 feet above the railroad at Colville, which would make a very easy grade for a road, and while I was not over the route for the proposed new road it was stated to me that it would be a very easy road to build.

This company has done considerable work toward opening up their marble deposits, principally, however, in clearing a place for the camp, building roads and work of this character. These deposits are exposed on the surface in many places so that no clearing and uncovering is necessary. As far as can be told from field observations it resists weathering well, being changed only very little on the exposed surface. The deposits are stratified, the individual layers being very thick and usually steeply inclined. The strike is almost due east and west and the deposits dip to the north.

The country rock over a large area here is limestone, which is much less broken wherever exposed than it is in many places in Stevens county and in fact very good sized blocks should be quarried here almost from the surface. The color of this marble varies much from pure white to almost black with various mixtures and markings of the white and dark. The company has a water power right on Stensgar Creek that is capable of furnishing power to run the plant. There is also plenty of timber on the property for all purposes and taken on the whole the property is very well situated for economic

working. The company intends to install machinery for working these deposits as soon as it can be obtained from the East.

This company had at the quarry (Jan. 1, 1903,) ready to be installed, the following machinery: Wardwell steam channeler, a steam gadder, a circular marble saw, lathe and polishing machine of large capacity, hydraulic ram with necessary piping to elevate water from the creek to the quarries proper, and three derricks. The company also has a portable steam saw mill for cutting lumber.

Thin sections of these marbles viewed under the microscope show that the individual grains vary considerable in size, ranging from those that are one-fifteenth of a millimeter to those that are as much as one millimeter in diameter. The pure white is the most coarsely crystalline of all marbles found in this locality. The grains in the white marble are quite uniform in size and are very closely knit or united together. In some of the sections examined there are seams of coarse grained material running through the fine grained.

In ordinary light the sections have a somewhat dirty appearance, more marked in places, however, than in others, and with well marked cleavage planes. In polarized light polysinthetic twinning is very noticeable.

The chemical composition of the marble from these deposits is shown by the following analyses. Two samples were analyzed from the Crystal property, one of which was the coarse grained white, while the other was somewhat finer grained and dark colored. In each case the samples are seen to have about the same amount of magnesia and to be dolomites or magnesian limestones:

	White.	Dark.
Silica ($Si\ O_2$)	0.91	0.98
Iron ($Fe_2\ O_3$)	None	None
Alumina ($Al_2\ O_3$)	None	None
Lime ($Ca\ O$)	31.80	30.08
Magnesia ($Mg\ O$)	20.68	22.21
Carbon dioxide ($C\ O_2$)	46.64	46.70
Water and undetermined substances	None	None
	100.03	99.97

Samples of the blue, gray and white marbles from the quarry of the Crystal Marble Co. were tested to determine the

crushing strength and the results are shown in Table I. The two samples of the blue which were tested had a crushing strength of 24,000 and 23,200 pounds to the square inch and a samples of the gray marble were found to have a crushing strength of 15,420 and 20,600 pounds to the square inch. Two modulus of elasticity of 8,250,000 and 5,220,000 pounds to the square inch. Three samples of the coarse white marble from this property had a crushing strength of from 11,870 to 13,600 pounds to the square inch, and a modulus of elasticity of from 2,372,000 to 8,200,000 pounds to the square inch.

The coarse grained white marble from this property as shown in Table II. has a specific gravity of 2.744, while the other grades have a specific gravity of 2.875. The white has a ratio of absorption of .17 of 1 per cent. of its weight and a pore space or porosity of .464 of 1 per cent. of its mass. The other samples tested show a ratio of absorption of from .10 to .18 of 1 per cent. of the weight of the samples and a porosity of from .291 to .518 of 1 per cent. of their mass. Samples after having been for twenty days in a moist atmosphere containing Co_2 showed the following results: A sample of the coarse grained white weighing 59.35 grams was unaffected, while a sample of the fine grained blue weighing 47.173 grams had lost at the end of the twenty days .004 of a gram.

Samples were alternately frozen and thawed each day for a period of twenty days and at the end of the period the loss in weight was carefully determined, the results being shown in Table III. The coarse grained white lost .025 of 1 per cent. of its weight, the fine grained dark blue lost nothing, while the other samples ranged from .005 to .024 of 1 per cent. of their entire weight. Samples were placed in a muffle furnace and gradually heated to a temperature of 800° F. and then cooled, some gradually and others suddenly. The samples, so far as could be told, were all uninjured. Samples were then heated to a temperature of 1,200° F. and when cooled were found to be calcined and easily crumbled and when exposed to the air for ten days had practically fallen to pieces.

The marble from the property of the Crystal Marble Co. takes a good polish, is a trifle harder than the Georgia or the

Vermont marble, and has a higher specific gravity than the average run of marbles. It is above the average in crushing strength, while its ratio of absorption is about normal. This marble is well suited for all the ordinary purposes for which marble is used, such as exterior building material, interior furnishing and decorative purposes, monuments, etc. The stone carves well and is suited to carved and ornamental work. These deposits differ from many of the Stevens county deposits in that they contain nothing but the standard grades of marble with the ordinary blue, gray and white colors with various mixtures of these. The property is better situated with regard to transportation than many of the Stevens county deposits and this is a point in its favor. The material is not so badly checked and broken on the surface and lies in a better position for quarrying than much of the Stevens county marble.

Keystone Marble Co.—The property of this company is about sixteen miles north and a little east of Colville in the foot-hills of the western slope of the Pend d'Oreille range of mountains, and on the head waters of Clugston creek. The deposits are in sections 1 and 12, T. 37 N., R. 39 E., and are reached by a wagon road from Colville to Echo and then up Clugston creek for about seven miles. The road to Echo is comparatively level, while the road up Clugston creek has a gradual ascent but is a fairly good mountain road most of the distance. The nearest point to the railroad from this property is Bossburg, a station on the S. F. and N., and distant from the property eight and one-half miles with an easy grade for a road. This company owns four claims of twenty acres each or eighty acres in all. In addition to the above the company has a water power right on Clugston creek about four miles from the quarry.

Considerable work has been done on this property toward opening it up but no machinery has been installed as yet. The work has all been done in one place and a depth of about fifteen feet has been reached. Exposures of these deposits vary considerably in appearance, in places being quite solid and free from checks, while in others they are badly broken on the surface at least.

These deposits vary considerably in color, ranging from almost pure white to almost black. There is also a pinkish colored marble found in these deposits which is very handsome. There are various shades and markings of the ordinary gray marbles. Exposures of these marbles indicate that they will resist weathering well as they are changed but little on the surface. The deposits are massive rather than stratified and the ridge in which they occur trends almost due north and south. The country rock along the road from Echo to the quarry is shale, slate, limestone and marble.

Thin sections of the marble from these deposits show that there is considerable variation in the size of the individual particles composing them, the white, some of it at least, being the coarsest grained of these deposits, the grains being as much as one and one-half millimeters in diameter, while the smaller ones are not more than one-tenth of a millimeter in diameter. In ordinary light the sections have a more or less clouded appearance and in places show very plainly the characteristic calcite cleavage. The grains are irregular in outline and appear to interlock in rather a complex manner. In polarized light the light and dark bands due to polysynthetic twinning so common in calcites are very marked.

The following chemical analyses show the composition of three of the different varieties of the marble found in these deposits. The one marked dark gray was almost black:

	White.	Gray.	Dark Gray.
Silica ($Si\ O_2$)	0.98	0.82	1.89
Ferric iron ($Fe_2\ O_3$)	Trace	Trace	.....
Ferrous iron ($Fe\ O$)	.....	.....	Trace
Alumina ($Al_2\ O_3$)	.....	.....	.....
Lime ($Ca\ O$)	53.96	54.81	42.60
Magnesia ($Mg\ O$)	1.25	0.70	10.05
Carbon dioxide ($C\ O_2$)	43.76	43.56	44.63
Water at 110° C. ($H_2\ O$)	.....	.....	.....
Water above 110° C. ($H_2\ O$)	.....	.....	.....
	99.95	99.89	100.17

From the above analyses it is seen that the marbles from these deposits, with the exception of the very dark gray, are practically free from magnesium and all impurities of an in-

jurious nature. The composition of this marble is practically the same as that from the quarry of the Jefferson Marble, Mining & Milling Co., as shown in Table V.

Two samples of the coarse white marble from the Keystone Marble Company's property were tested and as shown in Table I had a crushing strength of 6,280 and 11,600 pounds to the square inch, with a modulus of elasticity of 5,780,000 pounds to the square inch. Samples of the blue marble from the same property had a crushing strength considerable greater, being 14,360 and 16,000 pounds to the square inch for the two samples tested. The modulus of elasticity was 9,-014,000 and 11,330,000 pounds to the square inch. This marble has a specific gravity of 2.734. The ratio of absorption of the coarse white is .1 of 1 per cent. of its weight and of the light blue 1.02 per cent. of the weight. The pore space or porosity of the coarst white is .364 of 1 per cent., while that of the light blue is 2.83 per cent. of its mass.

Samples of the coarse white and the white and blue mixed were exposed for a period of twenty days in a moist atmosphere of Co_2, after which they were weighed and it was found that a sample of the white weighing 42.43 grams had lost .01 of a gram, while a sample of mottled blue and white weighing 8.505 grams lost in weight .005 of a gram. Samples were tested to determine the effect of high temperatures by gradually heating them to a temperature of 800° F. and cooling some of them suddenly, while others were allowed to cool slowly, and in both cases the specimens appeared but little injured. At 1,200° F. the samples were calcined and practically destroyed and after being exposed to the air for a few days crumbled and fell to pieces.

Tests were also made by alternately freezing and thawing each for a period of twenty days and at the end of this time the samples were weighed and as shown in Table III. the coarse white lost .058 of 1 per cent., the white and blue lost .043 of 1 per cent., and the light blue .002 of 1 per cent. of the entire weight of each.

The crushing strength of the marble from the property of the Keystone Marble Co. is about equal to that of the better

grades of marble being produced in the United States. The specific gravity and ratio of absorption are about the same as they are in other marbles. This marble takes a very high polish and is easy to work. The property contains a number of different grades and colors, the predominating colors, however, are the standard white, gray and blue, with mixtures of these in varying proportions. There is also some white mixed with yellow, which if it occurs in any quanity it would be a valuable decorative stone. The deposit is some distance from a railroad and the material would have the additional expense of being hauled by teams for several miles.

The Standard Marble-Onyx Co.—This company has some property in sections 13 and 18, T. 35 N., R. 39 and 40 E., and about four miles east and a little south of Colville. The property is very easy of access, there being a good wagon road that passes along one side of the property. This is one of the oldest marble locations of any place in Stevens county. The company owns 652 acres in this tract.

These deposits are massive and rise up from the road and bottom of the gulch to an altitude of one hundred feet. The deposits are considerably broken on the surface, and depth at least would have to be obtained before good sound marble could be found. The principal color is a gray with more or less white mixed through it. The deposits seem to have a fairly uniform texture throughout. This material has been burned for lime, but it does not make a good lime, which is probably on account of the large amount of magnesia in the deposits. These limestone deposits occur in contact with granites and are found lapping up onto them.

Thin sections of this limestone when viewed under the microscope show it to be made up of grains which vary in size from those that are not more than one-twentieth of a millimeter in diameter to those that are one millimeter in diameter. The individual particles are irregular in outline, are very close together, and interlock very firmly. In ordinary light it has a somewhat clouded appearance and very few cleavage planes are noticeable. In polarized light the polysynthetic twinning of the calcites is quite noticeable.

The following chemical analysis shows the composition of the material from the deposits owned by the Standard Marble-Onyx Co.:

Silica ($Si O_2$)	0.82
Ferric iron ($Fe_2 O_3$)	0.63
Ferrous iron ($Fe O$)	Trace
Alumina ($Al_2 O_3$)	.....
Lime ($Ca O$)	32.77
Magnesia ($Mg O$)	19.02
Carbon dioxide ($C O_2$)	46.73
Water at 110° C. ($H_2 O$)	.....
Water above 110° C. ($H_2 O$)	.....
	99.97

The analysis shows this marble to contain a considerable amount of magnesia and it what would be called a magnesium limestone.

One sample of this stone was tested and found to have a crushing strength of 21,500 pounds to the square inch and a modulus of elasticity of 5,120,000 pounds to the square inch. The specific gravity as shown in Table II. is 2.873, the ratio of absorption is .16 of 1 per cent. of its weight, and the pore space or porosity was found to be .455 of 1 per cent. of the mass of the stone. A sample after having been alternately frozen and thawed each day for a period of twenty days was found to have lost .008 of 1 per cent. of the weight of the sample. After having been for a period of twenty days in a moist atmosphere containing CO_2 it was found that a sample which originally weighed 63.375 grams had lost .001 of a gram in weight.

Samples were placed in a muffle furnace and gradually heated to a temperature of 800° F., after which some of them were allowed to cool slowly, while others were cooled suddenly. In each case the samples were practically uninjured. Samples were then heated to a temperature of 1,200° F. and allowed to cool slowly. When cooled they were found to be calcined and after being left in the air for a few days they crumbled and fell to pieces.

The Colville Marble Co.—The property of this company is situated on the north fork of Mill creek about sixteen miles northeast of the town of Colville. The company has located a large tract of land in this locality for marble, there being

about one thousand acres in all. The property is reached by a wagon road from Colville up Mill creek and for a considerable part of the distance it is a very good road for a mountain road. The deposits are from 2,500 to 3,000 feet above sea level or 898 to 1,398 feet above Colville, which is the nearest point on the railroad.

Very little work has been done on any of the deposits in this locality and for that reason it is not possible to say what will be found when depth is obtained but on the surface the deposits are badly broken. There are a number of colors shown in this locality varying from almost pure white to black. The black material occurring in this property and designated as black marble is more of a calcareous shale than anything else and is very badly broken, so that nothing but very small pieces could be obtained. The texture of the material of these deposits varies considerable, in some cases being quite fine, while in others it is what would be called rather coarse.

Along the road up Mill creek shales and slates are the prevailing formations. At the old mill site a short distance up the stream limestone occurs and a hole has been drilled to a depth of eleven hundred feet in prospecting for oil and it is said to be in limestone for the entire distance.

An examination of specimens of these marbles under a strong magnifying glass shows that it varies from a fine to quite a coarse texture but the grains in any one sample seem to be quite uniform in size.

The following chemical analyses show the composition of the cream white and the very dark gray or almost black:

	White.	Dark Gray.
Silica ($Si O_2$)	2.61	3.12
Ferric iron ($Fe_2 O_3$)	.....	0.12
Ferrous iron ($Fe O$)	.....	0.81
Alumina ($Al_2 O_3$)	.....	.....
Lime ($Ca O$)	53.68	52.04
Magnesia ($Mg O$)	0.76	0.67
Carbon dioxide ($C O_2$)	42.89	43.22
Water at 110° ($H_2 O$)	.....	.....
Water above 110° C. ($H_2 O$)	.....	.....
	99.94	99.98

The analyses show these deposits to be quite free from impurities with the exception of a small amount of silica. The dark gray sample also contains a little iron and this is probably the cause of its color.

The marble deposits of this area are situated on the east, north and west sides of the town and distant from it from three to ten miles. The deposits are situated in the foot hills and easy of access as good wagon roads are already constructed. These deposits have not been developed to as great an extent even as some of the other deposits in Stevens county and in fact most of them have been located within the last two or three years; some of them, however, have been located considerably longer. The occurrence of these deposits in general is similar to that of the others in Stevens county, being found in conection with granite, quartzite, shales and slates.

Chewelah Area.

The Great Western Marble Co.—The Great Western Marble Co. owns 120 acres about four miles northwest of Chewelah in Sec. 32, T. 33 N., R. 40 E. and 80 acres in Sec. 14, T. 33 N., R. 38 E. The property in Sec. 32 is very easy of access as it is only a short distance from tne Spokane Falls & Northern Railroad, and the place where the company has started to open up the deposit is not more than about one-fourth of a mile from the railroad. The altitude of the quarry opening is but little above the railroad and a tram could be easily constructed from it to the railroad.

The company had not done a very large amount of work last July toward the development of its property and in fact was just beginning active operation. A few small openings had been made but not enough work had been done in any one place to show anything very definite. These deposits vary in color, in places being very light colored and almost white, while in other places they are very dark red with almost every variation between these two that may be produced by different combinations of the red and light colored material. The deposits are not very distinctly stratified but are as a general thing what would be called massive. They resist well the

action of the atmospheric agencies and are little decomposed even on the surface. The material is somewhat broken on the surface. The company is putting up a plant in Seattle for cutting and polishing their material and working it in general.

Thin sections of the material from these deposits when viewed under the microscope show that in the main the individual particles composing the marble are very small and of quite uniform size with the exception of an occasional very thin seam in which the grains are much larger. In ordinary light the thin sections have a very dirty appearance and are almost opaque. They show very plainly dark and light irregular bands crossing the sections which give to it a banded or schistose structure. There are also occasional small seams of quartz found in the sections. In polarized light the appearance is much the same as in ordinary light, none of the marked characteristics of calcite being very noticeable.

The following chemical analyses show the composition of a sample of the pinkish white and also the dark pink colored material from these properties. They contain considerable silica and magnesia and are quite hard:

	Pinkish White.	Dark Pink.
Silica ($Si\ O_2$)	5.28	17.59
Ferric iron ($Fe_2\ O_3$)	0.64	0.56
Ferrous iron ($Fe\ O$)	1.01	1.06
Alumina ($Al_2\ O_3$)	2.58	0.48
Lime ($Ca\ O$)	28.83	26.52
Magnesia ($Mg\ O$)	17.28	15.46
Carbon dioxide ($C\ O_2$)	44.27	38.25
Water at 110° C. ($H_2\ O$)	.....	Trace
Water above 110° C. ($H_2\ O$)	.....	.....
	99.89	99.92

Samples of the marble from the property of the Great Western Marble & Onyx Co. were tested and as shown in Table I. they had a crushing strength of from 14,560 to 20,950 pounds to the square inch and a modulus of elasticity of from 5,537,000 to 8,682,000 pounds to the square inch. It has a specific gravity of 2.874, a ratio of absorption of .03 of 1 per cent. of its weight and a pore space or porosity of .078 of 1 per cent. of the mass of the stone. Samples were alternately frozen and thawed each day for a period of twenty days, at

the end of which time they were weighed and found to weigh the same as they did before being frozen.

As shown by the tests this marble is above the average in crushing strength, has a high specific gravity and a very low ratio of absorption. It is well situated as regards transportation facilities, being only a very short distance from a railroad. The stone takes a good polish but is quite hard and this will tend to make it expensive to cut and polish this marble. The stone, however, when finished is very handsome and it may be that it will stand this expense.

The Royal Serpentine Marble Company.—This property is situated five miles almost due east from Chewelah and consists of 160 acres of deeded land. It is in Sec. 9, T. 32 N., R. 41 E. The property is easy of access and a fairly good wagon road has been constructed to the property. It is in the foothills of the mountains to the east of Chewelah at an altitude above the sea level of 2,510 feet, as indicated by barometer, or 820 feet above the valley at Chewelah.

Very little work has been done toward opening up or developing this property. A few small openings, however, have been made and some samples taken out. These deposits are distinctly stratified and dip to the north at an angle of 45°. The color varies considerable but some shade or marking of green is the prevailing one. In places, however, a light gray is found. These deposits appear fairly solid and in places, at least, some medium sized blocks could be obtained even on the surface. These deposits occur in contact with granite and in places the granite comes to the surface on the tops of the hills and the limestone is found on all sides and practically surrounding it. Quartzite is also found in this locality.

Thin sections of this material when examined under the microscope show it to be a mixture of serpentine and calcium carbonate. It is what would be called fine grained and the individual particles of calcite are of quite uniform size. In places grains of serpentine are found which are as much as three millimeters in diameter, while in other cases they are less than one millimeter in diameter. Viewed in ordinary light the sections have a clouded and dirty appearance. In

polarized light the polysinthetic twinning of the calcite is very noticeable, while the serpentine shows a very marked mesh structure. In places the serpentine occurs in distinct grains, while in others it is more of an amorphous mass disseminated throughout the stone.

The following chemical analysis shows the composition of the material from these deposits:

Silica ($Si\ O_2$)	17.67
Ferric iron ($Fe_2\ O_3$)	0.92
Ferrous iron ($Fe\ O$)	0.62
Alumina ($Al_2\ O_3$)	4.61
Lime ($Ca\ O$)	30.92
Magnesia ($Mg\ O$)	16.32
Carbon dioxide ($C\ O_2$)	25.08
Water at 110° C. ($H_2\ O$)	.....
Water above 110° C. ($H_2\ O$)	3.86
	100.00

From the above analysis it appears very probable that the silica and all the magnesia are united to form the serpentine and that calcium carbonate occurs as pure calcium free from magnesia.

The samples of the marble from the property which were tested had a specific gravity of 2.817, a ratio of absorption of .06 of 1 per cent. of the weight of the sample, and a pore space or porosity of .175 of 1 per cent. of the mass of the sample. After having been alternately frozen and thawed each day for a period of twenty days it was found that it had lost .031 of 1 per cent. of its weight. It was subjected to a moist atmosphere, containing CO_2, for a period of twenty days and at the end of this time it was found that a sample weighing 57.12 grams had not diminished in weight. Samples heated to a temperature of 800° F. and cooled either gradually or suddenly were but little affected. When heated to a temperature of 1,200° F. and cooled the samples had changed to a much lighter color, but were not calcined as most of the other marbles were and were not materially affected.

Columbia Marble and Onyx Co.—The Columbia Marble and Onyx Co. have two hundred acres of land situated three miles almost due east of Chewelah in Secs. 7 and 8, T. 32 N., R. 41 E. The property is very easy of access, there being a

good road from Chewelah to it. The altitude of this deposit where the company has commenced to open a quarry is 1,900 feet above sea level or 210 feet above the railroad at Chewelah.

Very little work has been done on this property, only a few small openings having been made, and these do not show very much as regards the deposits. The country here is not as rough and broken as it is in connection with some of the other marble deposits of Stevens county. The deposits do not show any very distinct bedding planes but are considerably broken by joints and seams running through them. The material in these properties varies considerable in color, ranging from almost pure white through various shades of grays and in some places greens are found. The material is of medium grain and quite uniform. There is a small stream running through the property that would furnish power for driving machinery for working the deposits. The deposits lie practically flat or level and rise only a short distance above the valley. The principal formations in this locality, aside from the marble, are granite, quartzite and slate, and the limestones or marbles are found in contact with the granite and in places the marble is found lapping up onto either side of the granite ridges. This marble is harder than most marbles and should resist weathering quite well.

The following chemical analysis shows the composition of a sample of the white marble from these deposits:

Silica ($Si O_2$)	0.17
Ferric iron ($Fe_2 O_3$)	....
Ferrous iron ($Fe O$)	Trace
Alumina ($Al_2 O_3$)	....
Lime ($Ca O$)	43.24
Magnesia ($Mg O$)	10.78
Carbon dioxide ($C O_2$)	45.75
Water at 110° C. ($H_2 O$)	.....
Water above 110° C. ($H_2 O$)	.....
	99.94

From the above analysis it is seen that the marble from these deposits contains magnesia enough so that they would be classed as dolomites. The material from here takes a very high polish and is not as hard but what it can be easily worked.

The samples of the white marble from the property of the Columbia Marble Onyx Co., which were used in making the physical test, were found to have a specific gravity of 2.754, a ratio of absorption of .15 of 1 per cent. of their weight, and a pore space or porosity of .38 of 1 per cent. of the mass of the samples. Tests were made by alternately freezing and thawing each day for twenty days samples that were saturated with water and at the end of the period it was found that there had been a loss in weight of .046 of 1 per cent. A sample of this marble was exposed for a period of twenty days in a moist atmosphere of CO_2 and at the end of the time it was found that a sample weighing 58.41 grams had lost .005 of a gram in weight. Samples were tested by being placed in a muffle furnace and heated to a temperature of 800° F. and some of them allowed to cool slowly, while others were cooled suddenly. In neither case were the samples materially injured. When heated to a temperature of 1,200° F. and cooled they were found to be ruined and in a few days' exposure to the air fell to pieces completely.

Standard Marble-Onyx Co.—The property owned by this company in this locality is about five miles southwest from Chewelah and consists of 160 acres of land. It is in Sec. 19, T. 32 N., R. 40 E. The property is easy of access and a good road could be easily constructed to it.

The company has done very little work on the property up to the present time but an order has been placed for a very complete quarry outfit and it looks as if it is the intention to begin work at once. The deposits occur on either side of a narrow gulch and rise in precipitous bluffs as much as one hundred feet above it. This material varies in appearance, there being various shades and colors. The prevailing color, however, is dark red. These deposits are badly broken on the surface, but may improve as depth is reached. The material in these deposits is very fine grained and somewhat harder than ordinary marble. These deposits occur in contact with slates and in fact the country rock is principally slate in this immediate locality, while along the road to the north of these great bluffs of quartzite are found.

Chewelah Mottled Marble Co.—Almost due west from Chewelah, a distance of one and a half miles, is situated the property of this company, consisting of eighteen acres of land, fifteen of which are marble land. The wagon road from Colville to Sprindale passes by the property and makes it very easy of access.

These deposits rise in a steep bluff from forty to fifty feet above the wagon road but do not extend very far back to the west from it and it appears to be only a local occurrence of this material. To the north of these deposits, which extend along the road for about one-half a mile, immense bluffs of massive quartzite are found, while to the west of them are slates. These deposits are massive and show various colors and combinations of colors, the prevailing ones, however, being reds of different shades. The deposits lie on the face of a ridge which extends almost due north and south.

The following chemical analysis shows the composition of an average sample of the material from this deposit:

Silica ($Si O_2$)	23.98
Ferric iron ($Fe_2 O_3$)	0.96
Ferrous iron ($Fe O$)	0.44
Alumina ($Al_2 O_3$)	....
Lime ($Ca O$)	22.51
Magnesia ($Mg O$)	16.43
Carbon dioxide ($C O_2$)	35.61
Water at 110° C. ($H_2 O$)	0.26
Water above 110° C. ($H_2 O$)	.....
	100.19

From the above analysis it will be seen that there is a large amount of silica, which exists as free silica, and this accounts very largely for the extreme hardness, brittle, and flinty character of the material. It also contains some magnesia and this also has a tendency to make it hard. The stone is very fine grained, would have a very low ratio of absorption, and should resist weathering well, but is so hard that it would be very expensive to work and it is very doubtful if it has much commercial value at the present time at least.

Northwestern Marble Co.—In Sec. 30, T. 32 N., R. 40 E. is located the deposits owned by the Northwestern Marble Co. This property consists of one hundred and sixty acres

of land, four and one-half miles southwest from Chewelah, which is the nearest point on the Spokane Falls & Northern Railway. This property was not visited by me and I know nothing about it except what I have been told. There is said to be a large body of marble at this place, the deposit being one-fourth of a mile wide, one-half a mile long, and showing an initial depth of 200 feet. The prevailing colors are from almost pure white, through various shades of blue, yellow and browns, with veinings of black and green.

In Sec. 18, T. 32 N., R. 41 E. limestone deposits are found and some of it has been used from which to manufacture lime. It varies in color in different parts of the deposits in places being almost white, while in others it is a very dark blue, and still others it has more or less of a greenish color on account of its having serpentine mixed with it.

The following chemical analysis shows the composition of the dark almost black variety that has been used in the manufacture of lime:

Silica ($Si\ O_2$)	15.18
Ferric iron ($Fe_2\ O_3$)	....
Ferrous iron ($Fe\ O$)	Trace
Alumina ($Al_2\ O_3$)	....
Lime ($Ca\ O$)	27.69
Magnesia ($Mg\ O$)	17.02
Carbon dioxide ($C\ O_2$)	40.55
Water at 110° C. ($H_2\ O$)	.....
Water above 110° C. ($H_2\ O$)	.....
	100.44

BOSSBURG AREA.

Bossburg is a small town on the Spokane Falls & Northern Railway, one hundred and eleven miles north and a little west of Spokane. The marble claims that have been located in this locality are across the Columbia river from Bossburg and northwest from it a distance of two and one-half miles. All the claims examined are in Sec. 13, T. 38 N., R. 37 E. The altitude of these deposits is from six to eight hundred feet above the Columbia river at Bossburg, and they could be easily reached by wagon road from this place.

But little work has been done on any of the claims located in this district, a few small openings only having been made

and in some cases at least these have been made mainly with powder and the marble injured more or less. The deposits through this locality vary in color from a fairly pure white to various shades and markings of gray and white. They vary somewhat in texture but in most cases are quite coarse grained. These deposits are distinctly stratified and lie practically horizontal and have every appearance of weathering very slowly.

The following chemical analyses show the composition of the white and light gray marbles from this locality:

	White	Light Gray
Silica ($Si O_2$)	2.49	0.13
Ferric iron ($Fe_2 O_3$)	0.49	.....
Ferrous iron ($Fe O$)	Trace	.....
Alumina ($Al_2 O_3$)	0.49	.....
Lime ($Ca O$)	31.56	54.95
Magnesia ($Mg O$)	18.56	0.54
Carbon dioxide ($C O_2$)	45.91	44.22
Water at 110° C. ($H_2 O$)	Trace	.....
Water above 110° C. ($H_2 O$)	Trace	.....
	99.95	99.84

From the above analyses it will be seen that some of the marbles from these deposits are dolomites and contain much magnesia, while in other places they are practically free from magnesia.

The samples of marble from this locality which were tested show it to have a specific gravity of 2.73, a ratio of absorption of .24 of 1 per cent. of its weight, and a pore space or porosity of .486 of 1 per cent. of its weight. Samples when heated to a temperature of 1,200° F. and cooled were found to be calcined and ruined. At a temperature of 800° F. the samples even when cooled suddenly were but little injured.

This marble takes a good polish and is easily worked and would be suitable for either exterior building material or interior finishing work.

Ryan Area.

Florentine Marble Co.—Ryan is a station on the Spokane Falls & Northern Railway, one hundred and eighteen miles from Spokane. The marble quarry that is being opened up here is one mile up the river from the station but it is right

along by the side of the track and a short spur could be put in which would make it very easy to market the marble as it could be loaded directly from the quarry or mill on the cars. The property owned by the Florentine Marble Co. is in Sec. 12, T. 38 N., R. 38 E., and consists of 312 acres of land.

The marble occurs on the face of a bluff that rises from the Columbia river to an altitude of perhaps 150 to 200 feet but does not extend back from the river to any very great distance. There has been considerable development work done toward opening up the deposits but no stone had been quarried at the time I was there (July, 1902). Across the Columbia river are large bluffs of limestone which appear similar to the material being worked by this company. The deposits of the Florentine Marble Company show somewhat of a bedded structure, are fine grained, mostly of a light gray color and a little harder than most marble but still not hard enough so but what they can be easily worked.

The following chemical analysis shows the composition of the material from these deposits:

Silica ($Si\ O_2$)	1.00
Ferric iron ($Fe_2\ O_3$)	....
Ferrous iron ($Fe\ O$)	....
Alumina ($Al_2\ O_3$)	....
Lime ($Ca\ O$)	53.96
Magnesia ($Mg\ O$)	1.60
Carbon dioxide ($C\ O_2$)	43.27
Water at 110° C. ($H_2\ O$)	Trace
Water above 110° C. ($H_2\ O$)	.....
	99.83

The above analysis shows these deposits to be practically free from magnesia and to contain very little impurities of any kind.

MARBLE AREA.

Columbia River Marble & Lime Co.—Marble is a small town on the Spokane Falls & Northern Railroad one hundred and twenty-two miles distant from Spokane and the limestone deposits are one mile farther up the railroad. What is known as the Columbia River Marble & Lime Co. have five claims located here. These claims are in Secs. 22 and 27, T. 39

N., R. 39 E. and are very easy of access as the railroad passes through them and a spur could be built and the material loaded on the cars at very little expense.

These deposits vary much in color, ranging from light gray to almost black. Very little work has been done here and the deposits are not very promising for marble so far as the surface indications are concerned. The material is fine grained but the deposits are so badly broken on the surface at least that no very large blocks could be obtained. The deposits are stratified in places at least. Much of the limestone in this locality is covered with a layer of gravel and sand, which varies in thickness from six to fourteen feet. In places, however, the limestone rises above this layer of sand and gravel and occurs as steep bluffs of limestone from ten to thirty feet high.

Box Canyon Area.

Toronto Marble Co.—On the Pend d'Oreille river, sixty miles north of the town of Newport at what is known as Box Canyon the Toronto Marble Company owns three hundred acres of marble land. This property is in Sec. 20, T. 38 N., R. 43 E. and on the east side of the river. Newport is a small station on the main line of the Great Northern Railway and is distant from Spokane about forty miles. The property is easy of access as the Pend d'Oreille river is easily navigable from Newport to Box Canyon. Various colors are found here from pure white to quite dark blue, with various shades and markings of these. There is also a cream colored variety that is very handsome. The deposits are said to be very extensive, occurring in bluffs which rise five hundred feet above the water. I have had some very promising looking hand specimens from these deposits but as stated elsewhere in this report it is not possible to tell from hand samples very much about a quarry and it has not been possible for me to make a personal examination of this property. The marble takes a very high polish and if the deposits are not badly broken and large blocks can be obtained this should become a very important marble quarry.

Tests were made on two of the different grades of marble from this property to determine the crushing strength and modulus of elasticity and as shown in Table I. the white had a crushing strength of 19,830 and 24,510 pounds to the square inch and a modulus of elasticity of 7,865,000 and 7,071,000 pounds to the square inch. The dark gray had a crushing strength of 15,420 and 23,160 pounds to the square inch with a modulus of elasticity of 2,646,000 and 3,660,000 pounds to the square inch.

The crushing strength of this marble as shown by the above tests is considerable above the average of the marbles being quarried in the United States.

CHAPTER VI.

TABLE I—CRUSHING STRENGTH AND MODULUS OF ELASTICITY

Name of Quarry	Location	Description of Sample	Horizontal Section in inches	Area of Horizontal Section in sq. inches..	Height in inches...	Load at Rupture in pounds	Crushing Strength in pounds per square inch	Modulus of Elasticity in pounds per square inch...
GRANITE								
Miles C. Moore and Sons	Snake River	Light gray	2.06 x 2.06	4.24	2.08	45,500	10,730	5,070,000
Miles C. Moore and Sons	Snake River	Light gray	2.08 x 2.08	4.33	2.01	71,000	16,400	5,135,000
Miles C. Moore and Sons	Snake River	Light gray	1.98 x 2.04	4.04	2.10	63,450	15,660	1,532,000
J. A. Soderberg	Index	Light gray	1.99 x 2.04	4.06	2.06	59,200	14,580	2,463,000
J. A. Soderberg	Index	Light gray	2.06 x 2.02	4.16	2.02	69,190	16,610	3,252,000
J. A. Soderberg	Index	Light gray	2.00 x 1.98	3.96	2.01	55,200	13,900	4,440,000
Wash. Monumental and Cut Stone Co.	Little Spokane River	Light gray	2.00 x 1.98	3.96	2.07	62,500	15,800	2,058,000
Wash. Monumental and Cut Stone Co.	Little Spokane River	Light gray	2.01 x 2.05	4.12	2.04	53,000	12,870	1,800,000
TUFA								
Lilliwaup Stone Quarry	Lilliwaup Falls	Dark gray	2.00 x 1.94	3.88	1.95	40,000	10,000	3,576,000
Lilliwaup Stone Quarry	Lilliwaup Falls	Dark gray	2.02 x 2.05	4.14	2.02	48,000	11,590	2,664,000
Wash. Monumental and Cut Stone Co.	Bossburg	Light gray	2.00 x 1.96	3.92	1.90	36,400	9,300	1,320,000
Wash. Monumental and Cut Stone Co.	Bossburg	Light gray	1.92 x 1.75	3.36	1.94	26,000	7,730	6,550,000
SANDSTONE								
The Tenino Stone Quarry Co.	Tenino	Light greenish gray	2.00 x 2.00	4.00	2.14	23,000	5,750	1,288,600
The Tenino Stone Quarry Co.	Tenino	Light greenish gray	2.07 x 2.07	4.29	1.98	14,000	3,270	1,170,800
The Tenino Stone Quarry Co.	Tenino	Light greenish gray	2.03 x 2.09	4.24	1.96	22,050	5,200	551,000
Chuckanut	Chuckanut Bay	Bluish gray	2.12 x 2.12	4.49	2.04	24,000	5,340	871,500
Chuckanut	Chuckanut Bay	Bluish gray	2.20 x 2.20	2.16	4.84	52,000	10,740	1,518,000
Chuckanut	Chuckanut Bay	Bluish gray	2.20 x 2.22	2.10	4.88	54,000	11,070	1,158,000
Stuart Island	Stuart Island	Dark brown	1.65 x 1.72	2.84	1.63	25,250	8,900	....
Wilkeson	Wilkeson	Light gray from lower ledge	1.58 x 1.59	2.51	1.53	18,000	7,160	....
Wilkeson	Wilkeson	Light gray from lower ledge	1.63 x 1.63	2.66	1.49	20,450	7,680	....
Wilkeson	Wilkeson	Light gray from upper ledge	....	....	....	43,350	10,840	....
Wilkeson	Wilkeson	Light gray from upper ledge	1.72 x 1.71	2.94	1.70	27,000	9,180	....
Eureka	Cumberland	Light gray	1.85 x 1.91	3.52	1.92	12,400	3,520	....
Eureka	Cumberland	Light gray	2.07 x 2.13	4.41	2.01	14,500	3,280	712,100
W. W. Evans	Cumberland	Light gray	2.00 x 1.96	3.92	2.06	29,000	7,400	280,000

TABLE I — CRUSHING STRENGTH AND MODULUS OF ELASTICITY—*Concluded*

Name of Quarry	Location	Description of Sample	Horizontal Section in inches	Area of Horizontal Section in sq. inches	Height in inches	Load at Rupture in pounds	Crushing Strength in pounds per square inch	Modulus of Elasticity in pounds per square inch
MARBLE								
Keystone Marble Co.	Colville	Coarse white	1.95 x 1.96	3.82	1.96	24,000	6,280	....
Keystone Marble Co.	Colville	Coarse white	1.93 x 1.95	3.76	1.95	43,600	11,600	5,780,000
Keystone Marble Co.	Colville	Blue	1.92 x 1.92	3.69	1.90	53,000	14,360	11,330,000
Keystone Marble Co.	Colville	Blue	1.92 x 1.90	3.65	1.91	58,400	16,000	9,014,000
Crystal Marble Co.	Colville	Blue	2.05 x 2.05	4.20	2.04	86,400	20,600	....
Crystal Marble Co.	Colville	Blue	2.00 x 2.01	4.02	2.05	62,000	15,420	....
Crystal Marble Co.	Colville	Gray	2.04 x 2.05	4.18	2.06	100,350	24,000	8,250,000
Crystal Marble Co.	Colville	Gray	1.94 x 1.96	3.80	1.86	88,000	23,200	5,220,000
Crystal Marble Co.	Colville	White	2.00 x 1.98	3.96	1.96	53,900	13,600	2,450,000
Crystal Marble Co.	Colville	White	2.03 x 2.00	4.06	2.00	48,200	11,870	2,372,000
Crystal Marble Co.	Colville	White	2.06 x 2 06	4.24	2.00	54,640	12,880	8,200,000
The Standard Marble and Onyx Co.	Colville	Blue	1.90 x 1.96	3.72	1.85	80,000	21.500	5,120,000
Spokane Marble Co.	Milan	Dark	2.03 x 1.99	4.04	2.06	42,000	10,400	4,208,000
Spokane Marble Co.	Milan	Dark	2.03 x 2.06	4.18	2.05	41,600	9,950	3,625,000
Spokane Marble Co.	Milan	Dark	2.04 x 2.03	4.14	2.03	34,000	8,210	3,309,000
Spokane Marble Co.	Milan	Light yellow	2.03 x 2.06	4.18	2.01	56,800	13,590	11,023,000
Spokane Marble Co.	Milan	Light yellow	2.02 x 2.04	4.12	2.04	50,200	12,180	5,640,000
Spokane Marble Co.	Milan	Light yellow	2.02 x 2.00	4.04	2.02	60,000	14,820	3,876,000
Great Western Marble and Onyx Co.	Chewelah	Columbian	2.01 x 2.02	4.06	2.02	59,100	14,560	5,537,000
Great Western Marble and Onyx Co.	Chewelah	Columbian	2.00 x 2.01	4.02	2.01	66,000	16,420	5,617,000
Great Western Marble and Onyx Co.	Chewelah	Columbian	2.03 x 2.02	4.10	2.02	85,000	20,950	8,682,000
Toronto Marble Co.	Ione	White	2.02 x 2.02	4.08	2.03	100,000	24,510	7,071,000
Toronto Marble Co.	Ione	White	2.03 x 2.03	4.12	2.04	81,700	19,830	7,865,000
Toronto Marble Co.	Ione	Dark gray	2.01 x 2.01	4.04	2.01	62 300	15,420	2,646,000
Toronto Marble Co.	Ione	Dark gray	2.02 x 2.02	4.08	3.02	94,500	23,160	3,660,000
Federal Marble Co.	Northport	Light gray	2.02 x 2.02	4.08	2.02	53,000	12,990	5,500,000
Federal Marble Co.	Northport	Light gray	2.00 x 2.00	4.00	2.00	46,800	11,700	4,219,000
The United States Marble Co.	Valley	Diamond black	2.01 x 2.04	4.10	2.00	130,000	31,710	11,055,000
The United States Marble Co.	Valley	Diamond black	1.98 x 1.95	3.86	2.00	107,450	27,800	11,813,000
The United States Marble Co.	Valley	Green from near Intern'l boundary	2.01 x 1.98	3.98	2.00	92,000	23,110	10,975,000
The United States Marble Co.	Valley	Green from near Intern'l boundary	2.00 x 2.00	4.00	2.00	54,000	13,500	4,207,000

TABLE II — SPECIFIC GRAVITY, POROSITY, RATIO OF ABSORPTION AND WEIGHT PER CUBIC FOOT

Weights are in grains and fractions thereof

Name of Quarry	Location	Description of Samples	Dry Weight of Sample	Weight of Sample after soaking 60 hours	Weight of water absorbed	Ratio of absorption	Weight of Sample suspended in water	Specific Gravity	Percentage of pore space or porosity	Weight of dry stone in pounds per cu. ft.*
GRANITE										
Giles and Peat	Medical Lake	Light gray	102.062	102.624	.562	.55	63.98	2.676	1.452	164.149
Miles C. Moore and Sons	Snake River	Light gray	114.417	114.825	.408	.36	71.69	2.677	.969	165.015
Wash. Monumental & Cut Stone Co.	Little Spokane River	Light gray	98.700	99.385	.685	.69	61.87	2.679	1.843	163.680
J. A. Soderberg	Index	Light gray	85.040	85.451	.411	.48	53.97	2.743	1.308	167.420
TUFA										
Lilliwaup Stone Quarry	Lilliwaup Falls	Dark gray	43.749	45.780	2.031	4.64	27.705	2.726	11.235	150.615
Wash. Monumental & Cut Stone Co.	Bossburg	Dark gray	81.975	88.420	6.445	7.86	50.750	2.621	17.075	135.[illegible]
SANDSTONE										
Wilkeson, Lower Ledge	Wilkeson	Light gray	37.574	39.195	1.621	4.31	23.410	2.652	10.027	148.554
Wilkeson, Upper Ledge	Wilkeson	Light gray	47.945	49.925	1.980	3.13	29.850	2.649	10.125	148.193
Chuckanut	Chuckanut Bay	Bluish gray	65.168	68.095	2.927	4.47	41.275	2.727	10.910	151.224
Eureka	Cumberland	Bluish gray	49.288	51.932	2.644	5.36	30.545	2.628	12.355	143.369
W. W. Evans	Cumberland	Bluish gray	34.243	35.770	1.527	4.76	21.470	2.681	10.607	148.641
Sucia Island	Sucia Island	Dark brown	59.757	61.535	1.798	2.92	37.130	2.642	7.364	152.343
Stuart Island	Stuart Island	Dark brown	54.040	55.025	.985	1.82	34.240	2.724	1.736	166.612
Tenino Stone Quarry Co.	Tenino	Light greenish gray	67.532	73.075	5.543	8.21	42.340	2.681	18.001	136.829

TABLE II—SPECIFIC GRAVITY, POROSITY, RATIO OF ABSORPTION AND WEIGHT PER CUBIC FOOT—Concl.

Name of Quarry	Location	Description of Samples	Dry Weight of Sample..	Weight of Sample after soaking 60 hours..........	Weight of water absorbed	Ratio of absorption.....	Weight of sample suspended in water.........	Specific Gravity...	Percentage of pore space or porosity	Weight of dry stone in pounds per cu. ft.*.......
		MARBLE								
The U. S. Marble Co.	Valley	Diamond Black	65.025	65.115	.090	.14	43.300	2.908	.401	180.272
Keystone Marble Co.	Colville	Coarse white	42.455	42.512	.057	.10	26.870	2.724	.364	179.337
Keystone Marble Co.	Colville	White and blue	68.534	68.775	.241	.36	43.310	2.717	.846	168 959
Keystone Marble Co.	Colville	Light blue	109.446	110.600	1.154	1.02	59.850	2.763	2.880	171.514
The Jefferson Marble, Mining and Milling Co.	Colville	Dark blue	53.497	53.535	.038	.07	33.840	2.594	.184	161.166
The Jefferson Marble, Mining and Milling Co.	Colville	White with yellow	63.580	63.660	.010	.12	40.210	2.720	.341	167.170
The Jefferson Marble, Mining and Milling Co.	Colville	Fine white	45.300	45.461	.161	.35	28.650	2.719	.957	166.634
Columbia Marble and Onyx Co.	Chewelah	White	58.437	68.518	081	.15	37.340	2.754	.380	170.171
Toronto Marble Co	Ione	Blue and white	66.510	66.665	.155	.23	43.350	2.872	.664	177.591
The Standard Marble and Onyx Co.	Colville	Blue	63.380	63.481	.101	.16	41.360	2.873	.455	178.026
The North Amer. Marble & Onyx Co.	Valley	Pink with white	48.020	48.072	.052	.17	31.150	2.858	.308	177.432
Spokane Marble Co.	Milan	White with green	46.729	46.883	.154	.33	29.400	2.696	.881	166.334
Crystal Marble Co.	Colville	Coarse white	59.364	59.465	.101	.17	38.735	2.748	.464	169.023
Crystal Marble Co.	Colville	Coarse white	42.182	42.253	.071	.16	24.055	2.878	.475	178.291
Crystal Marble Co.	Colville	Fine blue with white	36.858	36.916	.058	.16	24.055	2.878	.451	178.332
Crystal Marble Co.	Colville	Mottled blue and white	50.798	50.890	.092	.18	33.130	2.875	.518	178.088
Crystal Marble Co.	Colville	Fine dark blue	47.173	47.221	.048	.10	30.765	2.875	.291	175.434
The Royal Serpentine Marble Co.	Chewelah	Fine grained dark	57.138	57.170	.032	.06	36.860	2.817	.175	175.035
Great Western Marble and Onyx Co.	Chewelah	Fine grained light	76 492	76.513	.021	.03	49.755	2.874	.078	178.753
The U. S. Marble Co.	Bossburg	Blue with white	54.895	55.030	.135	.24	34.790	2.730	.486	169.103
Washington State Marble Co.	Valley	Pink	93.309	94.515	1.255	1.32	60.358	2.829	3.578	173 834

* 1 cubic foot of water =62.245 lbs.

TABLE III — FREEZING AND THAWING TESTS

NAME OF QUARRY	LOCATION	DESCRIPTION OF SAMPLE	Dry weight in grains	Dry weight after 20 days exposure......	Loss in weight	Loss per cent.
GRANITE						
Giles and Peat	Medical Lake	Light gray	102.062	102.000	.062	060
Miles C. Moore and Sons	Snake River	Light gray	114.417	114.375	.043	.036
Washington Monumental and Cut Stone Co.	Little Spokane River	Light gray	98.700	98.630	.070	.070
J. A. Soderberg	Index	Light gray	85.040	85.005	.035	.041
TUFA						
Lilliwaup Stone Quarry	Lilliwaup Falls	Dark gray	43.749	43.690	.059	.134
Washington Monumental and Cut Stone Co.	Bossburg	Light gray	81.975	81.731	.244	.297
SANDSTONE						
Wilkeson, Lower Ledge	Wilkeson	Light gray	37.574	37.049	.082	.218
Wilkeson, Upper Ledge	Wilkeson	Light gray	47.945	47.900	.045	.093
Chuckanut	Chuckanut Bay	Bluish gray	65.168	65.128	.050	.076
Eureka	Cumberland	Light gray	49.288	48.975	.313	.635
W. W. Evans	Cumberland	Light gray	34.243	34.065	.178	.519
Sucia Island	Sucia Island	Dark brown	59.737	59.702	.035	.058
Stuart Island	Stuart Island	Dark brown	54.040	54.032	.008	.014
Tenino Stone Quarry Co.	Tenino	Light greenish gray	67.532	67.352	.180	.266

TABLE III — FREEZING AND THAWING TESTS—*Concluded*

Name of Quarry	Location	Description of Sample	Dry weight in grains.......	Dry weight after 20 days exposure......	Loss in weight	Loss per cent.
		MARBLE				
The U. S. Marble Co.	Valley	Diamond black	65.025	65.020	.005	.007
Keystone Marble Co.	Colville	Coarse white	42.455	42.430	.025	.058
Keystone Marble Co.	Colville	White and blue	68.538	68.505	.029	.043
Keystone Marble Co.	Colville	Light blue	109.446	109.443	.003	.002
The Jefferson Marble, Mining and Milling Co.	Colville	Dark blue	53.497	53.470	.027	.050
The Jefferson Marble, Mining and Milling Co.	Colville	White with yellow	63.580	63.553	.027	.042
The Jefferson Marble, Mining and Milling Co.	Colville	Fine white	45.300	45.270	.030	.066
Toronto Marble Co.	Ione	Blue and white	66.510	66.510	.000	.000
The Standard Marble and Onyx Co.	Colville	Blue	63.380	63.375	.005	.008
The North American Marble and Onyx Co.	Valley	Pink with white	48.020	48.013	.007	.014
Columbia Marble and Onyx Co.	Chewelah	White	58.437	58.410	.027	.046
Spokane Marble Co.	Milan	White with green	46.729	46.640	.089	.019
Crystal Marble Co.	Colville	Coarse white	59.364	59.350	.014	.025
Crystal Marble Co.	Colville	Coarse white	42.182	42.175	.007	.016
Crystal Marble Co.	Colville	Fine blue with white	36.858	36.850	.008	.024
Crystal Marble Co.	Colville	Mottled blue and white	50.798	50.795	.003	.005
Crystal Marble Co.	Colville	Fine dark blue	47.173	47.173	.000	.000
The Royal Serpentine Marble Co.	Chewelah	Fine grained dark	57.138	57.120	.018	.031
Great Western Marble and Onyx Co.	Chewelah	Fine grained light	76.492	76.492	.000	.000

TABLE IV — EFFECT OF CARBONIC ACID IN A MOIST ATMOSPHERE ON SAMPLES OF MARBLE

Time 20 Days

NAME OF QUARRY	DESCRIPTION OF SAMPLE	Weight at 110° C. before treatment ...	Weight at 110° C. after treatment...	Loss in weight
		In grams	In grams	
The United States Marble Co.	Diamond black	65.020	65.015	.005
Keystone Marble Co.	Coarse white	42.430	42.420	.010
Keystone Marble Co.	White and blue	68.505	68.500	.005
The Jefferson Marble, Mining and Milling Co.	White with yellow	63 553	63.545	.008
The Jefferson Marble, Mining and Milling Co.	Fine white	45.270	45.266	.004
Toronto Marble Co.	Blue and white	66.510	66.505	.005
The Standard Marble and Onyx Co.	Blue	63.375	63.374	.001
The North American Marble and Onyx Co.	Pink with white	48.013	48.010	.003
Columbia Marble and Onyx Co.	White	58.410	58.405	.005
Spokane Marble Co.	White with green	46.640	46.638	.002
Crystal Marble Co.	Coarse white	59.350	59.350	.000
Crystal Marble Co.	Coarse white	42.175	42.172	.003
Crystal Marble Co.	Fine blue	47.173	47.169	.004
Crystal Marble Co.	Mottled blue and white	50.795	50.792	.003
Hertzell and Kyle	Fine grained dark	57.120	57.120	.000
The U. S. Marble Co., from Bossburg.	Gray and white	54.895	54.880	.015

TABLE V — CHEMICAL ANALYSES OF WASHINGTON BUILDING AND ORNAMENTAL STONES

NAME OF QUARRY	LOCATION	DESCRIPTION	Silica SiO_2	Alumina Al_2O_3	Ferric Oxide Fe_2O_3	Ferrous Oxide FeO	Lime CaO	Magnesia MgO	Carbon dioxide CO_2	H_2O at 110°	H_2O above 110°	Alkalies and undetermined
GRANITE												
			Per ct.	Per ct	Per ct	Per ct	Per ct	Per ct	Per ct	Per ct	Per ct	Per ct.
Giles and Peat	Medical Lake	Gray	68.24	16.30	1.37	2.13	3.20	1.88	....	0.24	0.24	6.30
Miles C. Moore and Sons	Snake River	Gray	71.70	14.54	1.46	1.80	3.13	0.39	....	....	0.92	6.06
Wash. Monumental & Cut Stone Co.	Little Spokane River	Gray	71.98	15.07	1.97	0.82	2.46	0.58	....	....	0.20	6.92
J. A. Soderberg	Index	Gray	67.45	13.04	5.56	2.78	4.68	2.65	....	....	0.27	3.57
TUFA												
Lilliwaup Stone Quarry	Lilliwaup Falls	Dark gray, fine	60.58	18.42	7.90	....	8.16	1.53	....	1.81	1.83	....
Wash. Monumental and Cut Stone Co.	Bossburg	White, coarse	63.34	13.01	8.51	....	6.30	0.53	....	trace	....	5.14*
SANDSTONE												
												Total
Wilkeson	Wilkeson	White	98.11	0.07	0.25	0.64	0.22	0.12	....	....	0.76	100.22
Chuckanut	Chuckanut Bay	Light gray, very fine	90.19	1.92	1.42	2.08	0.59	1.78	....	0.97	1.53	100.30
Eureka	Cumberland	White	96.65	0.06	0.27	0.63	0.63	0.22	....	trace	1.54	100.06
Sucia Island	Sucia Island	Dark gray, coarse	90.21	1.98	1.89	1.75	0.72	0.81	....	0.69	1.73	99.78
The Tenino Stone Quarry Co.	Tenino	Dark gray, medium	90.84	1.85	1.66	1.72	0.65	1.02	....	trace	2.39	100.03
SERPENTINE												
The U. S. Marble Co.	Valley	Green	15.30	3.00	2.32	trace	....	52.89	1.27	none	24.22*	100.00
The North Amer. Marble & Onyx Co.	Valley	Green	38.47	0.16	2.04	trace	....	39.86	4.84	trace	14.63*	100.00

* H_2O and undetermined matter, by difference.

TABLE V — CHEMICAL ANALYSES OF WASHINGTON BUILDING AND ORNAMENTAL STONES—Concluded

NAME OF QUARRY	LOCATION	DESCRIPTION	Silica SiO_2	Alumina Al_2O_3	Ferric Oxide Fe_2O_3	Ferrous Oxide FeO	Lime CaO	Magnesia MgO	Carbon dioxide CO_2	H_2O at 110°	H_2O above 110°	Alkalies and undetermined
MARBLE												
			Per ct.	Per ct	Per ct	Per ct	Per ct	Per ct	Per ct	Per ct	Per ct	Total
Columbia River Marble & Lime Co.	Marble	Black	23.32		0.19		42.46	0.32	33.44	0.05		99.78
The Jefferson Marble, Mining and Milling Co.	Colville	White	0.87		trace		55.11	0.21	43.77	0.05		100.01
The Jefferson Marble, Mining and Milling Co.	Colville	Pink	3.49	trace	0.24	trace	51.54	1.11	42.36	0.10		99.84
The U. S. Marble Co	Valley	Black	5.79	0.43	0.85		1.69	42.07	47.23		1.94*	100.00*
The North Amer. Marble & Onyx Co.	Valley	White	40.35			1.66	11.85	22.07	17.22		6.85*	100.00
Crystal Marble Co.	Colville	White	0.91			trace	31.80	20.68	46.64			100.03
Crystal Marble Co.	Colville	Gray	0.98				30.08	22.21	46.70			99.97
Pac. Coast Marble Tiling & Mfg. Co.	Valley	Black	27.11	1.90	2.44	1.80	23.68	15.45	19.30		8.32*	100.00
The North Amer. Marble & Onyx Co.	Valley	Pink	0.89			0.58		45.76	49.24		3.53*	100.00
Spokane Marble Co.	Milan	Black	27.93	2.32	2.08	2.38	13.05	27.74	11.33		13.17*	100.00
Keystone Marble Co.	Colville	Gray	0.82		trace		54.81	0.70	43.56			99.89
Chewelah Mottled Marble Co.	Chewelah	Pink	23.98		0.96	0.44	22.51	16.43	33.61	0.26		100.19
The Royal Serpentine Marble Co.	Chewelah	Black	17.67	4.61	0.92	0.62	30.92	16.32	25.08	trace	3.86*	100.00
Keystone Marble Co.	Colville	Dark gray	1.89			trace	43.60	10.05	44.63	trace		100.17
The Standard Marble & Onyx Co.	Chewelah	Light gray	0.82		0.63	trace	32.77	19.02	46.73			99.97
Columbia Marble & Onyx Co.	Chewelah	White	0.17			trace	43.24	10.78	45.75			99.94
Keystone Marble Co.	Colville	Cream white	0.98		trace		53.96	1.25	43.76			99.95
Great Western Marble & Onyx Co.	Chewelah	Pinkish white	5.28	2.58	0.64	1.01	28.83	17.28	44.27			99.89
B. Vogt	Chewelah	Gray	15.18			trace	27.69	17.02	40.55			100.44
Colville Marble Co.	Colville	Dark gray	3.12		0.12	0.81	52.04	0.67	43.22			99.98
Colville Marble Co.	Colville	Cream white	2.61				53.68	0.76	42.89			99.94
Great Western Marble & Onyx Co.	Chewelah	Dark pink	17.59	0.48	0.56	1.06	26.52	15.46	38.25	trace		99.92
Bryant property	Bossburg	White	2.94	0.49	0.49	trace	31.56	18.56	45.91	trace		99.95
Florentine Marble Co.	Ryan	Light gray	1.10				53.96	1.60	43.27	trace		99.83
The U. S. Marble Co	Valley	Light gray	0.13				54.95	0.54	44.22	trace		99.84
Washington State Marble Co.	Valley	Pink	18.18	0.44	0.45	1.17	24.74	66.10	38.18	0.05	0.69*	100 00
Washington State Marble Co.	Valley	Green	10.47	1.85	0.56	0 57	32.66	15.03	38.19	0.10	0.57*	100.00

* H_2O and undetermined matter, by difference.

TABLE VI.—CRUSHING STRENGTH IN POUNDS PER SQUARE INCH, SPECIFIC GRAVITY AND RATIO OF ABSORPTION OF BUILDING STONE OCCURRING OUTSIDE OF WASHINGTON.

Location of Stone	Comparative Strength in Pounds per square inch	Specific Gravity	Ratio of Absorption
GRANITE			
(1) Montello, Wisconsin	43,973	2.639	.079
(1) Granite City, Wisconsin	25,000	2.675	.133
(1) Berlin, Wisconsin	32,747	2.643	.143
(1) Granite Heights, Wisconsin	16,723	2.631	.180
(2) East St. Cloud, Minnesota	28,000	2.692	2.59
(2) Sauk Rapids	21,500	2.710	.190
(2) Beaver Bay, Minnesota	20,750	2.69	.140
(3) Fourche Mountain, Arkansas	29,000	2.642	1-1673
(3) Fourche Mountain, Arkansas	28,700	2.635	....
(3) Fourche Mountain, Arkansas	21,500	....	....
(4) Little Rock, Arkansas	22,388	....	....
(4) Little Rock, Arkansas	17,407	....	....
(4) Milbridge, Maine	19,917	....	....
SANDSTONE			
(2) Hinckley, Minnesota	19,000	2.470	4.98
(2) Dresbach, Minnesota	6,500	2.380	11.48
(2) Jordan, Minnesota	4,750	2.340	12.69
(1) Ablemans, Wisconsin	13,669	....	....
(1) Ablemans, Wisconsin	11,030	....	....
(1) Ablemans, Wisconsin	8,602	....	....
(1) Ablemans, Wisconsin	10,056	....	....
(1) Dunnville, Wisconsin	2,502	2.601	15.130
(1) Port Wing, Wisconsin	5,498	2.638	10.330
(1) Houghton, Wisconsin	4,549	....	....
(1) LaValle, Wisconsin	13,350	....	....
(1) Bayfield, Wisconsin	4,588	2.639	4.760
(5) Birdsboro, Pennsylvania	11,448	....	....
(5) Waltonville, Pennsylvania	14,000	2.350	1-27
(5) Waltonville, Pennsylvania	12,730	....	....
(5) Lumberville, Pennsylvania	22,250	2.660	....
(5) Laurel Run, Pennsylvania	17,600	2.660	1-900
(5) White Haven, Pennsylvania	29,252	....	....
(5) Portland, Connecticut	12,580	2.350	1-40
(5) Middletown, Connecticut	6,250	2.360	1-40
(5) E. Longmeadow, Massachusetts	12,330	2.480	....
(5) Medina, New York	16,031	2.400	1-53
(5) Marquette, Michigan	6,150	....	....
(6) St. Anthony, Indiana	3,000	....	3/40
(6) Riverside, Indiana	6,100	....	1/25
(6) Riverside, Indiana	6,800	....	1/50
(6) Worthy, Indiana	6,825	....	....
(6) Berea, Ohio	11,213	2.110	1/20
(6) Hummelstown, Pennsyluania	12,810	....	....
(6) Gunnison Colorado	5,250	2.200	.090
(6) Cleveland, Ohio	6,800	2.240	1/37
(6) N. Amherst, Ohio	5,450	2.140	1/99
(6) Angel Island, California	4,574	2.730	1/31
(6) San Jose, California	2,400	2.640	1/16
(6) Bass Island, Wisconsin	4,850	....	....

TABLE VI.—Concluded.

Location of Stone	Comparative Strength in Pounds per square inch	Specific Gravity	Ratio of Absorption
LIMESTONE			
(1) Knowles, Wisconsin	29,189	2.793	1.790
(1) Bridgeport, Wisconsin	10,112	2.740	5.460
(1) Bridgeport, Wisconsin	6,675	2.740	5.460
(1) Duck Creek, Wisconsin	23,783	2.843	.419
(1) Sturgeon Bay, Wisconsin	31,957	2.841	.190
(1) Sturgeon Bay, Wisconsin	39,983	2.700	.64
(1) Genesee, Wisconsin	36,731	2.833	1.10
(1) Genesee, Wisconsin	29,253	2.829	1.15
(1) Marblehead, Wisconsin	42,787	2.856	.31
(1) Lannon, Wisconsin	31,936	2.814	1.32
(1) Fountain City, Wisconsin	8,830	2.804	4.95
(1) Wauwatosa, Wisconsin	19,111	2.821	2.29
(1) Wauwatosa, Wisconsin	13,406	2.826	2.53
(1) Wauwatosa, Wisconsin	23,744		
(2) Red Wing, Minnesota	23,000	2.750	2.95
(2) Stillwater, Minnesota	10,750	2.590	2.19
(1) Kasota, Minnesota	18,500	2.640	2.51
(2) Mantorville, Minnesota	9,500	2.650	5.37
(2) Minneapolis, Minnesota	21,750	2.770	2.36
(7) Ellettsville, Indiana	6,700		1-31
(7) Ellettsville, Indiana	5,900		1-41
(7) Salem, Indiana	11,700	2.510	1-31
(7) Salem, Indiana	6,900		
(7) Bloomington, Indiana	4,200		1-14
(7) Bloomington, Indiana	5,700	2.460	1-19
(7) Bloomington, Indiana	8,000		1-33
(7) Romana, Indiana	7,000	2.480	1-39
(7) Bedford, Indiana	4,609	2.470	1-23
(7) Bedford, Indiana	14,000		
(7) Bedford, Indiana	6,500		1-24
(7) Salem, Indiana	8,900	2.510	1-31
MARBLE			
(1) Rutland, Vermont	11,892		
(1) Rutland, Vermont	13,864		
(1) Mountain, Vermont	12,833		
(1) Sutherland Falls, Vermont	16,156		
(1) DeKalb, New York	13,733		
(1) DeKalb, New York	10,478		
(1) DeKalb, New York	12,004		
(1) DeKalb, New York	13,772		
(1) Colton, California	17,783		
(1) Canaan, Connecticut	5,812		
(8) St. Joe, Arkansas	17,835	2.712	0.34
(8) St. Joe, Arkansas	10,447	2.697	0.33
(8) St. Joe, Arkansas	11,265	2.707	0.25
(8) Marble City, Arkansas	8,894	2.691	0.57
(8) Marble City, Arkansas	10,381	2.689	0.49
(8) Rhodes Mill, Arkansas	14,400	2.711	0.29
(8) St. Joe, Arkansas	6,728	2.693	0.37
(8) St. Joe, Arkansas	6,935	2.675	0.56
(8) Montgomery County, Pennsylvania	13,700		
(8) Dorset, Vermont	7,612	2.635	0.58
(8) Cararra, Italy	12,156	2.690	
(9) Georgia	10,000		
(9) Georgia	13,100	2.763	
(9) Georgia	11,400	2.717	
(9) Georgia	12,000	2.707	
(9) Georgia	10,900	2.734	
(9) Georgia	10,800		

(1) Wisconsin Geological and Natural History Survey, Bulletin No. 4, Building and Ornamental Stones, pp. 390-403, by E. R. Buckley.
(2) Geol. and Nat. Hist. Sur. of Minn., final report, Vol. I, pp. 196-200.
(3) Ann. Rept. Ark. Geol. Survey, Vol. II, 1890, pp. 4450, by J. F. Williams.
(4) Tests of Metals, Government Rep't., 1895, pp. 319-320.
(5) Apendix Ann. Rep't, Pa. State College, 1896, p. 30, (Brownstones).
(6) Twentieth Ann. Rep't, on The Geology and Natural Resources of Indiana, p. 323.
(7) Twenty-first Ann. Rep't, on The Geology and Natural Resources of Indiana, pp. 313-315.
(8) Ann. Rep't Ark. Geol. Survey, Vol. IV, 1890, p. 210, by T. C. Hopkins.
(9) Geological Survey of Georgia, Bulletin No. 1, p. 81.

CHAPTER VII.

CONCLUSIONS.

A comparison of the results of the physical tests made on the building stones of Washington in the preparation of this report with those from other places as shown in Table VI. will be helpful in determining the quality of Washington stone. The results of the chemical analyses are shown in Table V.

The granites being quarried in Washington at the present time are all of them about the same color, a light gray. The crushing strength ranges from 10,730 to 16,610 pounds to the square inch which is perhaps rather below the average for the granites that are being quarried in the United States. As has been already shown, however, those having the minimum strength are much stronger than is necessary for building purposes. The specific gravity of the Washington granite is practically the same as that of the best granites that are being quarried in other states. The ratio of absorption is a trifle higher than that of most granites but at the same time is not high enough to injure it in the least. The greatest ratio of absorption was in that from the Little Spokane river and it was only .69 of 1 per cent. and the least was in the sample from the Snake river where it was .36 of 1 per cent. The weight of the granite per cubic foot from the different localities differed less than four pounds and the average weight is 165 pounds to the cubic foot. The stone does not resist high temperatures very well being considerably injured at 800° F. to 1200° F.

The granite being quarried in Washington is a very good building material as shown by the comparison of it with other granites and by careful examinations of buildings where it has been used.

The sandstones that are being quarried in Washington at the present time have a crushing strength ranging from 3,280

to 11,070 pounds to the square inch and compare very favorably in this respect with many of the best sandstones that are being quarried in other states and in most cases at least is sufficient for use in the construction of any building. The specific gravity is higher than that of most sandstones. The weight per cubic foot as determined in the laboratory is from 143,369 to 166,612 pounds. The percentage of pore space or porosity in one case is as high as 18, but in most cases is about 10, which is about the same as that of many of the best sandstones. The sandstones of Washington vary somewhat in color and range from those that have a light color to those that have a dark color with a greenish cast to them.

The marbles of Washington occur principally in Stevens county. They are of various colors and range in texture from those that are very fine to those that are very coarse. The composition is quite variable in some cases being almost pure calcium carbonate, in others being magnesium carbonate with only traces of calcium carbonate, while in still others mixtures of calcium and magnesium carbonate are found in which there is more or less serpentine. The samples of marble used in making the physical tests shown in this report were perhaps hardly fair samples on account of the fact that many of the quarries are not developed to any extent as yet and the samples were necessarily from material that would not be as solid as it would be when a greater depth is reached. The results, however, of the tests of crushing strength show that the Stevens county marbles compare very favorably, as far as strength is concerned, with the best marbles from other parts of the United States. The specific gravity of these marbles is above the average being as high as 2.908 in the case of the "Diamond Black" from the quarry of The U. S. Marble Co. This same material also had the highest crushing strength of any sample tested, being 31,710 pounds to the square inch. The average specific gravity was about 2.75, which is about the same as that of the Georgia marbles. The porosity of the Washington marbles is low, being in all the samples tested, with the exception of two, less than 1 per cent.

In but very few cases have the marble deposits of Wash-

MICROPHOTOGRAPHS

OF THIN SECTIONS OF

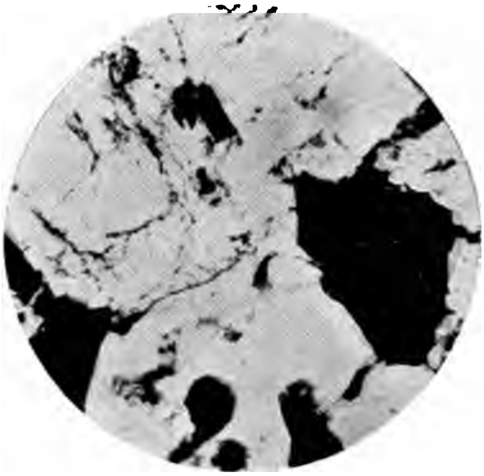
GRANITE, BASALT, TUFA, SANDSTONE, MARBLE, SERPENTINE AND LIMESTONE.

(Magnified Twenty Diameters.)

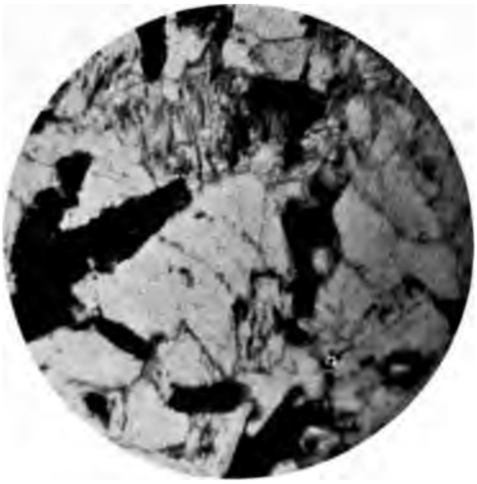
PLATE VIII.—MICROPHOTOGRAPHS.

Granite from the quarry above Index. This section consists of quartz, feldspar and mica, which are very intricately interwoven and interlocked. It shows very well the zonal structure which is so prominent in the granite from this locality. This figure shows considerable biotite, but at the same time it is not a very prominent constituent of the rock.

Granite from the Soderberg quarry below Index. This section is very similar to the preceding one, with the exception that this one shows hornblende instead of biotite. The close interlocking of the grains is well shown in this section also. The mineralogical composition of this granite is the same as that from above Index.



GRANITE FROM THE QUARRY ABOVE INDEX.



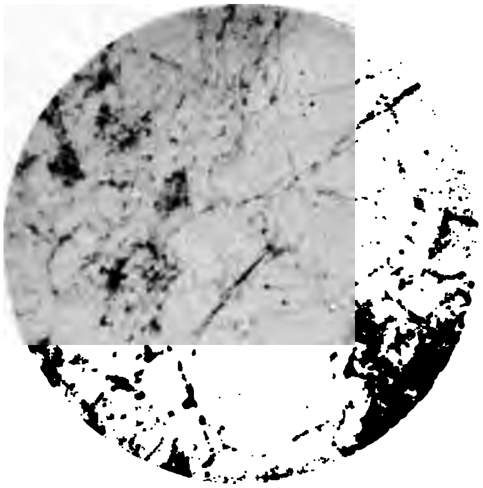
GRANITE FROM THE SODERBERG QUARRY BELOW INDEX.

PLATE IX.—MICROPHOTOGRAPHS.

Medical Lake granite. This section shows the mineralogical composition of this granite to be principally quartz, feldspar and biotite, with some hornblende. The grains are very intricately interwoven and intermixed, which makes this granite quite strong. The zonal structure of the feldspar is well shown here also.

Granite from the Little Spokane River. This section shows the very coarse texture of the Spokane granite. The minerals shown in this section are quartz and feldspar, which are closely interlocking.

GRANITE FROM THE QUARRY AT MEDICAL LAKE.



GRANITE FROM THE QUARRY ON THE LITTLE SPOKANE RIVER.

PLATE X.—MICROPHOTOGRAPHS.

Granite from the quarry of Miles C. Moore, on Snake River. This figure shows fairly well the texture of the Snake River granite.

Basalt from a quarry near Pullman. The section from which this cut was made shows well the porphyritic texture of this basalt, with the lath-shaped plagioclase feldspar. The rock has a very compact fine-grained texture.

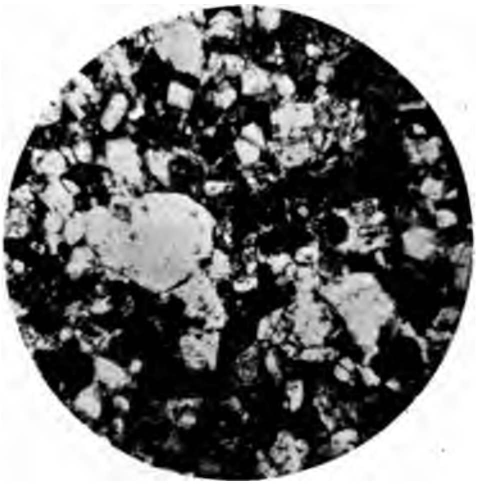
GRANITE FROM THE QUARRY OF MILES C. MOORE, ON SNAKE RIVER.

BASALT FROM A QUARRY NEAR PULLMAN.

PLATE XI.—MICROPHOTOGRAPHS.

Tufa from Lilliwaup Falls, on Hood's Canal. This figure shows nicely the feldspar crystals disseminated through the somewhat glassy ground mass. The crystal fragments in this rock are not closely interlocked, however, as they are in many rocks.

Tufa from near Bossburg, Stevens County. This figure shows the crystals and fragments of crystals, as well as the fragments of glassy ground mass. The crystals are principally feldspar. There are, however, smaller amounts of quartz, biotite, pyroxene and magnetite.



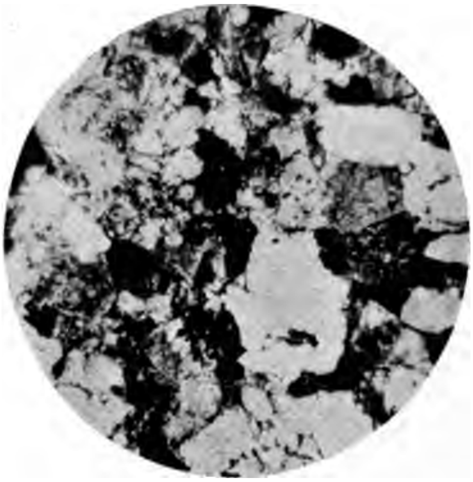
TUFA FROM LILLIWAUP FALLS, ON HOOD'S CANAL.

TUFA FROM NEAR BOSSBURG, STEVENS COUNTY.

PLATE XII.—MICROPHOTOGRAPHS.

Sandstone from the Sucia Island quarry. This section is composed principally of grains of quartz, which are rather angular in outline and vary somewhat in size. It also contains some feldspar grains scattered through it. The grains are closely compacted and firmly bound together.

Sandstone from the property of the Tenino Stone Quarry Co. This figure shows the small angular quartz grains, composing this stone, very nicely. The grains throughout are quite angular, with only once in a while one that is at all well rounded. The grains are not so well compacted and firmly bound together as they are in many of the sandstones. The grains are practically all quartz.



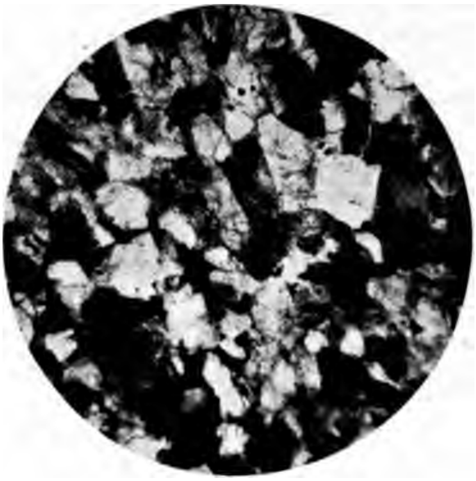
SANDSTONE FROM THE SUCIA ISLAND QUARRY.

SANDSTONE FROM THE QUARRY OF THE TENINO STONE COMPANY.

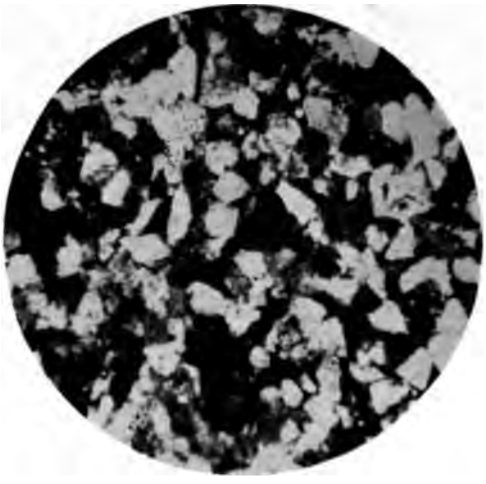
PLATE XIII.—MICROPHOTOGRAPHS.

Cumberland sandstone from the W. W. Evans property. This section is composed principally of grains of quartz, some of which are very angular, while others are well rounded. The grains vary considerable in size, but as shown in the cut none of them are more than medium size. The grains are quite well cemented together, but are not closely interlocking as they are in igneous rocks. The section shows the presence of an occasional grain of feldspar.

Sandstone from the Chuckanut quarry on Chuckanut Bay. The grains in this section are very angular and little rounded. They are also much smaller than those in any of the preceding sections. The grains are held firmly together by a cement composed principally of silica. Occasional grains of feldspar are mixed with the quartz grains.



SANDSTONE FROM THE W. W. EVANS QUARRY AT CUMBERLAND.

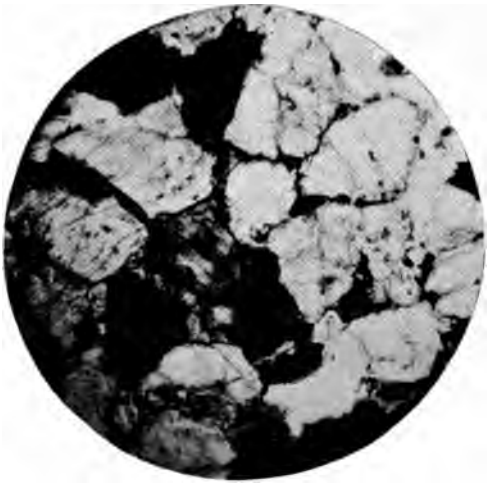


SANDSTONE FROM THE CHUCKANUT QUARRY.

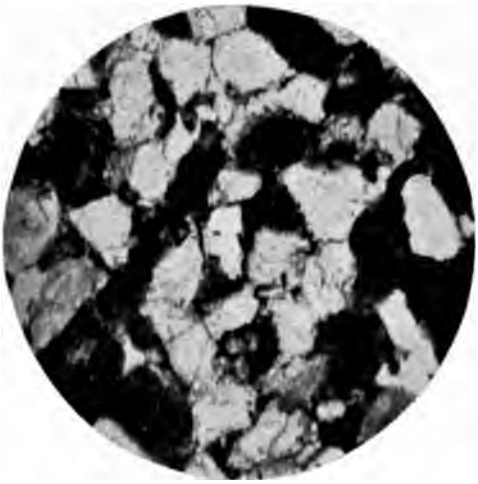
PLATE XIV.—MICROPHOTOGRAPHS.

Sandstone from Wilkeson. The texture of the sandstone from the lower ledge is well shown in this section. It is a very coarse grained stone, in which the individual grains composing it are in most cases quite well rounded. The structure is rather loose and open and the grains are only fairly well cemented.

Sandstone from Wilkeson. This section shows the texture of the stone from the upper ledge of this quarry. It is finer grained than that from the lower ledge of this quarry and is a little more compact. Most of the grains are well rounded, but in some instances they are quite angular.



SANDSTONE FROM THE LOWER LEDGE, WILKESON QUARRY.

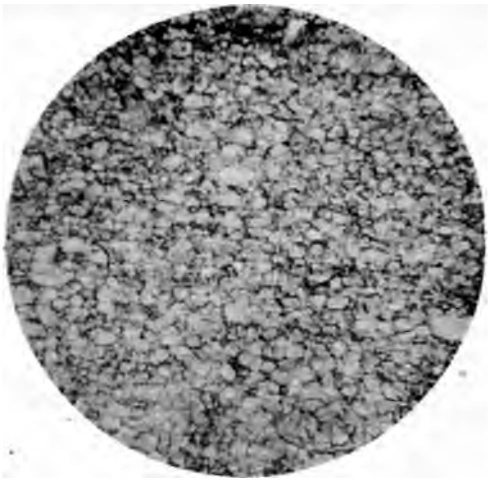


SANDSTONE FROM THE UPPER LEDGE, WILKESON QUARRY.

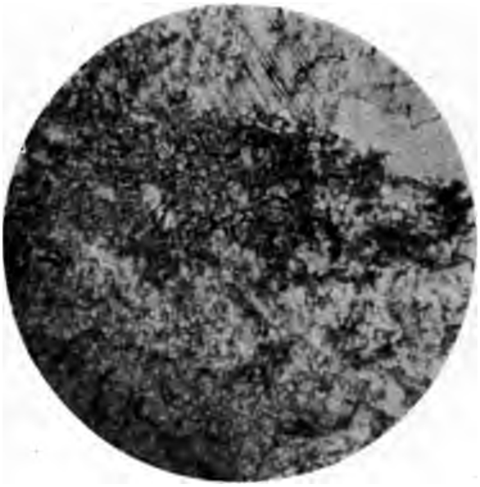
PLATE XV.—MICROPHOTOGRAPHS.

Marble from the quarry of the Jefferson Marble, Mining and Milling Co. The section from which the accompanying figure was taken is composed essentially of calcite. The grains are small but uniform in size and very closely interlocking. The sample from which the section was made was almost pure white and very fine grained.

Marble from the property of the North American Marble and Onyx Co. The section shows this marble to be a mixture of calcium carbonate and serpentine. The calcite grains vary somewhat in size but are very closely interlocking. The serpentine occurs in seams running through the section, and is not evenly distributed through it.



MARBLE FROM THE QUARRY OF THE JEFFERSON MARBLE, MINING AND MILLING CO.



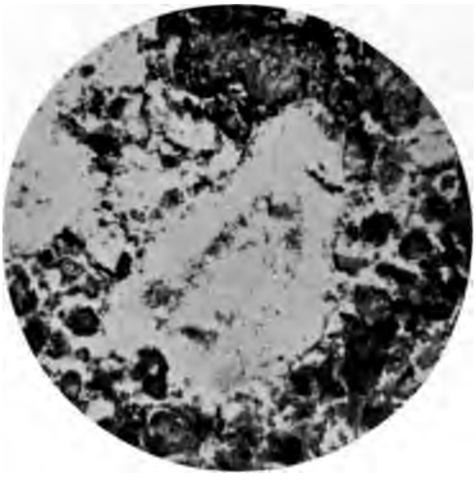
MARBLE FROM THE QUARRY OF THE NORTH AMERICAN MARBLE AND ONYX CO.

PLATE XVI.—MICROPHOTOGRAPHS.

The section from which the accompanying figure was made shows the texture of another sample from the property of the North American Marble and Onyx Co. It is very fine grained, almost amorphous, but there are some very long and narrow crystals scattered through the mass.

Serpentine from the property of the North American Marble and Onyx Co. The texture of the serpentine from this property is very well shown in the accompanying figure.

MARBLE FROM THE QUARRY OF THE NORTH AMERICAN MARBLE AND ONYX CO.



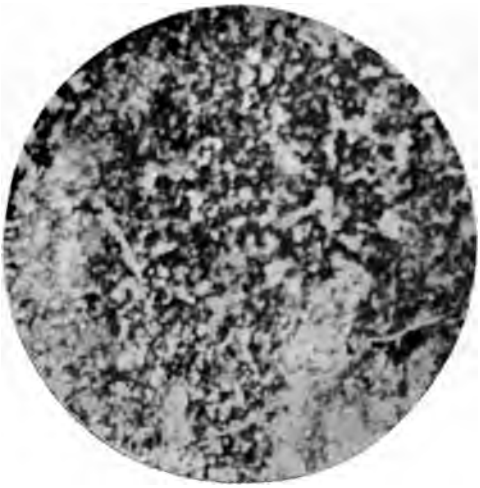
SERPENTINE FROM THE PROPERTY OF THE NORTH AMERICAN MARBLE AND ONYX CO.

PLATE XVII.—MICROPHOTOGRAPHS.

Limestone from the property of the North American Marble and Onyx Co. This figure is a splendid illustraticn of the way in which the individuals of the very coarse crystalline limestone from this property interlock. The material is coarsely crystalline, but the individuals are very closely bound together and the pore space is very small.

This figure shows the texture of the material from the quarry of the Pacific Coast Marble, Tiling and Manufacturing Co. The section is composed of calcite, serpentine and some clay material. The rock is very fine grained and compact.

LIMESTONE FROM THE PROPERTY OF THE NORTH AMERICAN MARBLE AND ONYX CO.

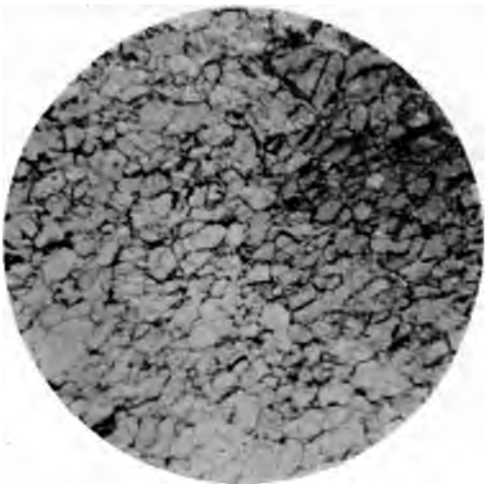


MARBLE FROM THE QUARRY OF THE PACIFIC COAST MARBLE, TILING AND MANUFACTURING CO.

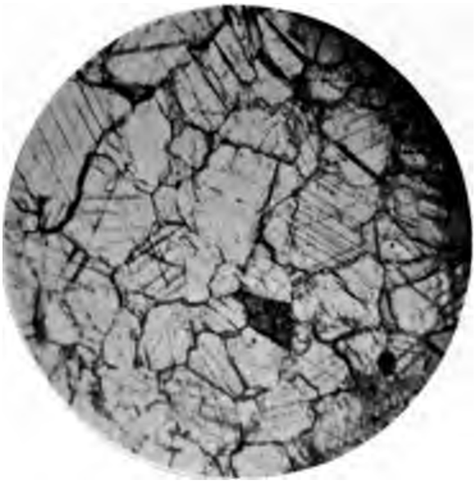
PLATE XVIII.—MICROPHOTOGRAPHS.

Marble from the property of the Crystal Marble Co. The section from which the accompanying figure was taken shows the texture of the gray marble. As shown by the figure it is made up of grains of calcite, which are quite uniform and of medium size. The stone is very close and compact, which accounts for its very low percentage of pore space.

Marble from the property of the Crystal Marble Co. The section from which the accompanying figure was made shows the very coarse texture of the white marble from this property. The section is made up of very coarse grains of calcite, which interlock in a very complex manner.



GRAY MARBLE FROM THE PROPERTY OF THE CRYSTAL MARBLE CO.



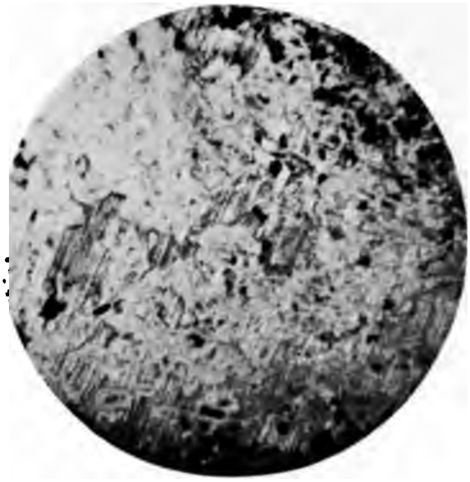
WHITE MARBLE FROM THE PROPERTY OF THE CRYSTAL MARBLE CO.

PLATE XIX.—MICROPHOTOGRAPHS.

Marble from near Milan. The figure shows serpentine principally, with a little calcite. It also contains some iron scattered through it.

Marble from near Milan. The section from which the accompanying figure was made is from material from the same locality as the preceding one. This figure shows some serpentine, but more calcite than the other.

MARBLE FROM NEAR MILAN.

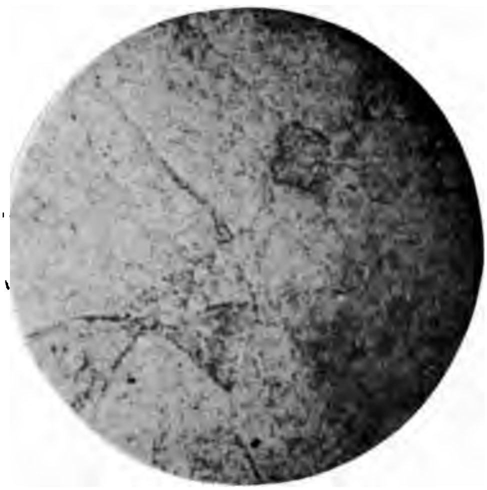


MARBLE FROM NEAR MILAN.

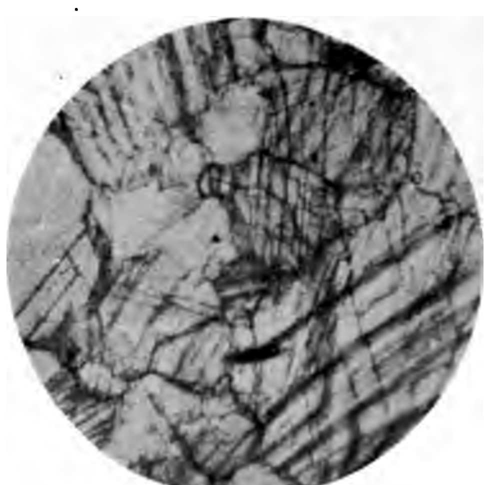
PLATE XX.—MICROPHOTOGRAPHS.

Marble from the quarry of the United States Marble Co. The section from which this cut was made was from a sample of what is known as their "Diamond Black." The cut shows the very coarse and compact texture of this material. The compactness and close union of the crystals account largely for its high crushing strength.

Marble from the property of the Keystone Marble Co. This cut shows the coarse texture of the white marble from this property. The crystals, while quite large, are firmly held together and very closely and intricately interlock.



MARBLE FROM THE QUARRY OF THE UNITED STATES MARBLE CO.



MARBLE FROM THE QUARRY OF THE KEYSTONE MARBLE CO

ington been developed to any very great extent and in fact it has not been more than about a couple of years since active work was begun on most of the properties that are being worked at present. Since that time a very large number of marble claims have been staked and much of the material that has been located will never be of any value as marble. In some cases it is so hard that it will be too expensive to work it, in others the question of transportation will prevent the working of the deposits at a profit, while in other places the deposits are so badly broken and shattered that they will be of no value as marble for building or decorative material except in a small way.

The general opinion seems to be that as depth is reached the seams that may occur on the surface will certainly disappear and that no matter how badly the marble may be broken on the surface it will be solid when a comparatively short distance below the surface is reached. This disappearance of these seams, however, as has been already shown, is only an apparent one in most cases at least unless a considerable depth has been reached and may be only apparent even then.

There are, however, in Stevens county quite a number of very promising marble properties both as regards the ordinary grades of marble as well as the more valuable decorative varieties.

CHAPTER VIII.

METHODS OF QUARRYING AND DRESSING STONE

GENERAL CONSIDERATIONS.

The rocks of the earth's crust are usually divided into three groups, as follows: (1) Sedimentary, (2) Igneous, (3) Metamorphic. Each of these groups has certain structural features which are very important factors in connection with the quarrying of the rock and which will have much to do in determining the method to be used in the quarrying of each group.

The sedimentary rocks are rocks that have been formed under water and for this reason should show more or less evidence of stratification unless it has been destroyed since the formation of the deposits. The layers in these sedimentary beds will vary from those that are an inch or less to those that are many feet in thickness. The planes of stratification in these deposits were originally, in most cases at least, nearly or quite horizontal and their present position is due to subsequent movements. These strata composing the sedimentary beds in many cases do not adhere firmly, due probably to the conditions under which they have been formed and the deposits may be separated very readily along certain planes and this is taken advantage of by the quarrymen and is a very great help in working the quarry. Again the thickness of these layers or the frequency with which they may be easily separated along certain planes has much to do with determining the size of the blocks that may be obtained and it also has much to do with the economical working of the quarry. If the beds are not too thick about all that is necessary in quarrying the stone is to put down holes or channels through one layer after another. This is especially true if the deposits are in a horizontal position. Where the layers are very thick and massive the cost of quarrying is greater as the stone has to be loosened along the under side also. This may be done by drilling and wedging and in some cases by wedging alone.

The uniformity of the beds in texture and color is another very important question as regards the economic quarrying of any deposit. The variation in texture of these bedded deposits is often a source of considerable additional expense as is well shown in some of the quarries of Washington where good and poor stone are found alternating throughout the deposit and in order to get the good stone a large amount of poor stone has to be removed and this of course increases the cost of the good stone. The position of stratified deposits, that is whether they are horizontal or inclined, frequently has much to do with the ease or difficulty with which they may be worked. Horizontal deposits have some things in their favor and on the other hand there are some things in favor of the inclined deposits. All things considered, however, the horizontal position is the one best suited to economical quarrying.

This bedded structure does not exist in the igneous rocks and it becomes necessary, especially in case of the very massive rocks, to split the stone by some means into proper sizes and this may be done by wedging or by what is known as gadding. There are, however, in all rocks, no matter whether igneous or sedimentary, more or less seams or fractures separating the rocks into blocks of different sizes and these are usually taken advantage of by the quarrymen. These seams and fractures are known as joints.

These joints vary much in size, in some cases being so fine as to be almost imperceptible, while in other cases they are capable of being traced very considerable distances. Professor Geikie * in discussing the joints in stratified rocks has the following to say:

"As a rule they are most sharply defined in proportion to the fineness of grain of the rock. In limestones and close-grained shales for example they often occur so clean-cut as to be invisible until revealed by fracture or by the slow disintegrating effects of the weather. The rock splits up along these concealed lines of division, whether the agent of demolition be the hammer or frost. In coarse textured rocks, on

* Text Book of Geology, pp. 524 and 525.

the other hand, joints are apt to show themselves as more irregular sinuous rents.

"As a rule, they run perpendicular, or approximately so, to the planes of bedding, and descend vertically at not very unequal distances, so that the portions of rock between them, when seen in profile, appear marked off into so many wall-like masses.

"An important feature in the joints of stratified rocks is the direction in which they intersect each other. In general they have two dominant trends, one coincident, on the whole, with the direction in which the strata are inclined from the horizon, and the other running transversely at a right angle or nearly so."

The frequency of joints in the sedimentary rocks varies much and in some deposits they are very plentiful while in others they are quite scarce. In cases where the strata or deposits have been very much disturbed, folded, and faulted the joints are much more common than where such changes have not taken place.

While joints occur in the igneous rocks such as granite, diabase, diorite, and basalt, they do not have the same regularity of arrangement that they have in the stratified deposits. In sedimentary rocks there are, in most cases at least, stratification planes along which they split more readily than across them and also the joints which usually intersect these at a high angle. In the igneous rocks the only divisional planes are the joint planes. The igneous rocks usually have two sets of these joints which intersect each other and separate the rock into blocks of various shapes and sizes. Sometimes there is still a third series of joints occurring in these rocks which in some respects is similar to the bedding planes in the sedimentary rocks. These last are well shown in places in the basalt area of eastern Washington.

In many cases where joints are very conspicuous on the surface they apparently disappear entirely as depth is reached. This disappearance as Merrill* states is probably only appar-

* Stones for Building and Decoration, p. 369.

ent and just as many really exist as at the surface, but on account of not having been exposed to the atmospheric agencies are not so readily noticed, and then again in some cases at least at considerable depths the rocks may be more or less firmly united along the joint planes. This may have been brought about by having some cementing material deposited in the joints or as Merrill* says by pressure.

This same authority in discussing the question of joints and their disappearance with depth gives an instance of a quarry of beautiful deep gray coarsely crystalline granitic rocks, which when first opened was found to contain so many joints that only very small and very irregular shaped blocks could be obtained, to show that this disappearance is only an apparent one:

"So abundant were these joints that on the suface for short distances the stones would often separate into slabs of but from one to two or three inches in thickness. At a distance of not above 25 feet from the surface the joints disappeared entirely, and large, handsome and apparently sound blocks were being taken out. Knowing, however, from the surface indications that the joints must be there nevertheless, I looked for them with care, and on the polished shaft of a finished monument was able to point out three running perpendicularly, each as fine, sharp and straight as though made with a glazier's diamond. They were simply so small as to be overlooked by others than an expert. Being there they are bound in time to open under the persuasive action of heat and frost. How long a time may elapse before they will open sufficiently to become conspicuous, can be determined only by actual experiment. The only safe way, however, is to avoid them wholly."†

In some rocks such for instance as the basalts still a different form of jointing is found which is due apparently to the cooling of the molten mass. This jointing gives rise to more or less regular shaped blocks which as a general thing are six sided and appear as hexagonal columns. These are

* Ibid.

† Stones for Building and Decoration, George P. Merrill, p. 369.

well shown in many places through the basaltic area of eastern Washington. These joints spoil the stone for dimension purposes as nothing but small blocks could be derived from a quarry in which this form of jointing occurs; fortunately however this form of jointing is not common and occurs only in rocks that would be used very little for building purposes on account of their hardness and color.

There is still considerable difference of opinion as to the cause of joints and no explanation that has been offered so far has been entirely satisfactory. By some authorities joints have been attributed to contraction from loss of heat or loss of moisture, by others compression has been considered an important factor, and by still others joints are supposed to have been produced by earthquakes. The indications are that in some particular case some one of these forces may have been the predominating one, while in others some other one may have been most active, but in all probability in most cases, if not in all, the joints are the result of a number of forces acting together. In a quarry the question is not so much, however, how joints have been formed as it is whether they exist or not in the rock that is to be quarried. If joints are absent it will take more work and hence cost more to quarry the stone than it will if they are present, while on the other hand if they occur too frequently they will spoil the stone for building purposes.

GRANITE QUARRYING.

The methods used in quarrying stone of course will vary with the kind and quality of the stone and the purposes for which it is intended. The object aimed at in most cases is the same, that is, to obtain large and well shaped blocks with as little work as possible. This should also be done so far as it is possible, without too much additional cost, without the aid of explosives of any kind on account of the sudden jar being very liable to develop minute fractures and injure the stone and perhaps completely shatter and destroy very valuable material.

The kind of material to be quarried will have much to do

IMPROVED STONE CHANNELING MACHINE, MANUFACTURED BY THE INGERSOLL-SERGEANT DRILL CO.

in determining whether or not explosives may be used and in the case of granite and that class of rocks there is much less danger from their use than there is in the case of marbles or sandstones. Then the greater hardness of the granite renders the quarrying of it, by other means than explosives, quite difficult and expensive.

The leading granite quarries of the United States such as those in Maine and Massachusetts use no machinery except the steam drill and hoisting apparatus. By means of the drills a series of what are known as lewis holes is put down to a depth dependent on the thickness of the sheets. These are then charged with medium charges and fired simultaneously. These lewis holes consist of a series of two or more holes drilled as closely together as possible, and then connected by knocking out the thin partition between them, forming thus one wide hole, having its greatest diameter in a plane with the desired rift. Blasts from such holes are wedgelike in their action, and by means of them larger and better shaped blocks can be taken out than would otherwise be possible. In quarries where the sheets are entirely free from one another this is all that is necessary to loosen the blocks from the quarry and they are then broken up with wedges. In many cases the sheets are thick enough so that it is necessary to drill a series of horizontal holes along the line where it is desired to break the rock from the bed and then complete the process with wedges.

MARBLE QUARRYING.

In the quarrying of marble and other soft rocks channeling machines are being used quite largely at the present time. These machines run on narrow tracks back and forth across the quarry bed and cut as they go vertical channels which are usually about one and a fourth inches wide and from four to seven feet deep. Some of these machines are so arranged that two channels are cut one on each side of the machine, at the same time and are then known as "Double Gang Machines," while others are arranged for cutting a channel on only one side of the machine at a time and are known as "Single Gang

Machines." These machines are practically locomotive engines which can be reversed without stopping.

These double machines carry on each side a gang of cutters composed of five steel bars from seven to fourteen feet long according to the depth of the channel to be cut. In each one of these gangs of five cutters, two have diagonal cutting edges, and three have their edges transverse. The center cutter extends the lowest and they altogether form a stepped arrangement each way from the center. When the machine is moving forward the three forward cutters, which include the center one operate and while moving in the opposite direction the other two with the center one perform the work. The object of the diagonal cutting edges is to insure an even bottom to the channel.

At the present time there are two distinct types of channeling machines which differ primarily in that in one case the gangs of drills or cutters are raised and dropped by means of a lever and crank arrangement while in the other type the blow is struck by the steam in the cylinder just as it is in the rock drill or steam hammer. The Wardwell machine is of the first type and is constructed either with a single or a double gang of cutters. It is claimed that these machines will strike 150 blows per minute on each side, and feed forward on the track ½ inch at each stroke or six feet per minute and cut from ½ to 1 inch in depth (according to the stone) each time passing over it.

The Sergeant channeler is of the second type or what is known as the direct acting machine. These are single gang machines and like the Wardwell single gang machines are capable of being so arranged that channels may be cut at almost any angle as well as vertical. The cutting points in this machine are the same as in others but they are attached rigidly by a clamp directly under the center line of the piston rod.

After these vertical channels are cut to the required depth a series of horizontal holes is drilled along the bottom of the block and it is then split from its bed by means of wedges. The operation of drilling these horizontal holes is known to the

quarrymen as "gadding" and special machines have been constructed for this purpose. In some cases diamond pointed drills, as well as the ordinary impact drills, are used for gadding. The horizontal holes are usually drilled to a depth equaling about one-half the width of the block to be extracted, however this as well as the frequency of the holes will depend very largely on the kind and character of the material.

The rate of cutting of channeling machines varies, as shown by the Arkansas Geological Survey * in limestones and marbles from 32 square feet of channel in ten hours to as high as 100 square feet and the cost of running channeling machines varies from $5 to as high as $10 for ten hours.

The bar channeler is also used to a considerable extent in some quarries at the present time. These are much cheaper than locomotive channelers and are capable of being used for various purposes. It is the same as a rock drill mounted on a quarry bar except that a gang of chisels is used instead of the drill. It may also be used for gadding and also for drilling plug and feather holes.

SANDSTONE QUARRYING.

Channeling machines are also used more or less in the quarrying of sandstones especially the softer ones. The prevailing method however is to loosen large blocks with powder and then work them into the required shapes and sizes. Deep holes are drilled in the rock and these are charged with heavy blasts of powder and then fired, and in this way large masses are loosened. In the Portland, Connecticut, quarries the most of the stone is loosened by blasting, the method used being as follows: "The holes are made by a crude machine driven by cranks, like an ordinary derrick, and are 10 inches in diameter and about 20 feet deep. Into these are put from 25 to 75 pounds of powder, contained in a flattened or oval tin cannister, with the edges unsoldered and closed at the ends by paper or cloth. This is placed in the hole in such a position that a plane passing through its edges is in line with the desired

* Arkansas Geological Survey, Annual Report, 1890, Vol. IV., p. 367.

break, and fired. In this way large blocks are freed from the quarry, and these are then broken to any required size as follows: The workmen first cut with a pick a sharp groove some 4 to 8 inches deep along the full length of the line where it is desired the stone shall break. Into this groove are placed, at intervals of a few inches, large iron wedges, which are then in turn struck repeated blows by heavy sledge-hammers in the hands of the quarrymen until the rock falls apart." *

OPENING THE QUARRY.

In opening up a stone quarry of any kind there are a number of things that should be taken into consideration and frequently many important points are overlooked or neglected and large sums of money squandered which might have been saved had these points been duly considered. Among the most important of these points are quality, quantity, position of the stone, and location. The position of a deposit, that is, if it be a bedded deposit at least whether it is horizontal or whether it is steeply inclined, may make difference enough in the expense of quarrying so that in one case it would be possible to work the deposits at a profit while in the other case it would not be possible to work them at a profit. It is not possible to determine the commercial value of a deposit from hand specimens as there are many things that cannot be told from small samples and it is necessary that the deposit should be studied as a whole.

The location of the quarry as regards transportation is a very important point at least in many cases. The ordinary grades of building stone have to be produced as cheaply as possible in order to compete with the cheaper grades of building material and on this account they must have the least possible cost for transportation. A quarry that might be worked at a profit when situated on a railway might have no commercial value when only a few miles from it. Only the most expensive varieties of marbles and stones used for decorative purposes can be profitably transported by wagon for even

* Stones for Building and Decoration, by G. P. Merrill, N. Y. 1891, p. 374.

short distances. In some cases certain stones can be quarried only to supply a local demand and this local demand may determine the output of the quarry so that the question of how much this local demand will be should be carefully considered.

If after having considered the above points very carefully it is decided to open a quarry on any particular deposit the next step is to determine the exact location of it and this is a question of no small importance and one that calls for the services of an experienced quarryman, that is one who has had experience in quarrying similar stone elsewhere. He should also have at least a fair knowledge of geology and the more he knows about it the better. The deposits should be pretty thoroughly prospected and for this purpose a diamond drill may be very helpful in gaining some knowledge, at least, of the interior of the deposits.

Where a quarry is being opened in a new region and the quality of the stone has still to be determined it is a good policy not to put in too expensive an outfit at first but start with a medium priced one and gradually add to it if the quality of the stone, with the development of the quarry, will warrant it.

"Professor W. L. Saunders,* in his notes on quarrying, estimates that a first-class equipment for quarrying dimension stone, which includes derricks, boilers, pumps, channeling machines, rock drills, pipe, blacksmith's tools and fittings, costs about $8,000; however, if the rock to be worked only promises well, but its quality or quantity is not assured, a good equipment, including channeling machine, rock drill, boiler, pump, derrick and hoisting apparatus, can be obtained for $3,500. It may not be advisable to purchase a channeling machine at first, and its omission from the list will greatly reduce the necessary outlay for the beginning of operations."

The prices of the different pieces of apparatus, as shown in the following list, will enable anyone to figure out the cost of any outfit he may desire:

* Arkansas Geological Survey, Annual Report, 1890, Vol. IV., p. 373.

Channeling machine, double	$2,000		
Channeling machine, single	1,700	to	$2,200
Bar channeler	1,000		
Steam drill, unmounted	170	to	415
Tripod	50	to	65
Quarry bar	175	to	250
Portable quarry gang saw	1,000	to	2,000
Derrick	200	to	800

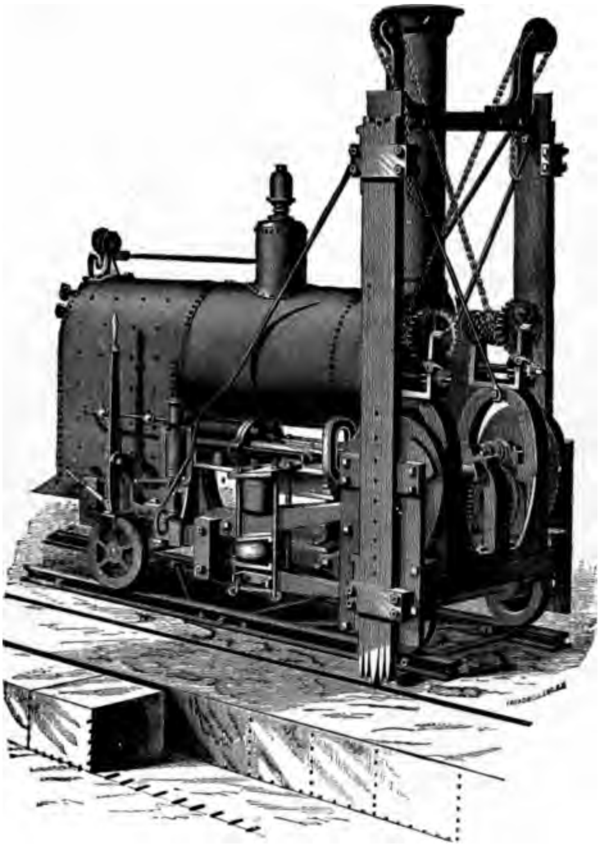
The above quotations are the catalogue prices for 1902 and many of them are subject to trade discounts. The cost of labor and tools will vary in different localities.

METHOD OF WORKING A QUARRY.

The method to be used in working a quarry should be determined quite largely at least by the kind of stone and the use for which it is desired. In addition to the above there will be many other things to be taken into consideration some of which in particular cases at least may be very important.

The quarrying of marbles, limestones, and some sandstones at the present time is done quite largely by the use of channeling machines of some kind while in the harder igneous rocks such as granite explosives are quite largely used for breaking the rock loose, after which the large masses are split and worked into sizes by hand. In the opening of a quarry, in which channeling machines are to be used, the usual thing to do is to remove the debris overlying the stone to be quarried and secure a comparatively level floor of the same size that it is desired to make the quarry. When this is done the channeling machine is put to work and a series of channels the required depth and distance apart are cut and one of the blocks loosened on the under side in some manner usually by wedging and then lifted out or it may be removed by blasting. After the first block is removed the others may be loosened on the under side either by gadding or by means of wedges. Then another layer is begun and removed in exactly the same manner and in this way the quarry floor may be carried down almost any depth provided the stone continues.

In some quarries what is known as the step or bench system is used and consists in having a ledge of varying width at the back wall each time instead of taking out an entire layer



WARDWELL DOUBLE GANG CHANNELING MACHINE FOR MARBLE OR LIMESTONE.

of the quarry floor. This will give to the back part of the quarry the appearance of a set of steps. If the quarry is to be worked after this plan the bar channeler is probably the best one to purchase, as it is much more easily moved from bench to bench. In the case of quarries worked by hand either one of the above plans may be followed.

USE OF EXPLOSIVES IN QUARRYING.

At one time the use of powder in the quarrying of building stone such as limestones, sandstones, and marbles was very general, but at the present time its use is very limited and especially so in the quarrying of marbles and limestones. It is used quite extensively however in quarrying granites and the harder kinds of stone and also to a limited extent in some sandstone and limestone quarries.

There are two principal reasons why explosives should not be used in quarrying marbles and the softer grades of building stone. First and most important is the fact that the stone is injured more or less by their use. The jar of the blast and the sudden strain produced will cause lines of weakness or open up hidden seams, defects which as Hopkins * says are "rendered doubly serious by the fact that they frequently do not appear until after the stone has been placed in the structure. This is well illustrated by the Carrara marble, of which it has been said that most of the stone used by the Romans before the invention of gunpowder is firm and sound, while much that has been used since gunpowder quarrying began shows signs of decay. The injurious effects of the blast are often greatly increased in the Carrara quarries by another sometimes equally serious shock, produced by the large masses being blown out of the quarry on the mountain top and falling or rolling 400 or 500 feet down the mountain side."

While there are very few marble quarries in which powder is used in the real work of quarrying still many of them use it in the removal and clearing away of the overlying worthless material. Even for this purpose however it should be used

* Arkansas Geological Survey, Annual Report, 1890, Vol. IV., p. 376.

with considerable care as otherwise there is danger of doing much injury to valuable material. In many places in Stevens County where marble quarries are being opened much time and money might be saved by an intelligent use of the ordinary black powders, but unless they are handled by some one who has some knowledge of their use much damage may result.

In quarrying ordinary dimension stone where the stone is to be used in foundations, retaining walls or similar uses where the question of durability is not so important a one powder may be used and with the proper handling good results obtained.

In the use of powder for quarrying dimension stone the following suggestions taken from the Arkansas Geological Survey Report, Vol. IV., 1890, pp. 377 and 378, may be found helpful:

"The limited number of directions in which a rock is liable to break is determined by the shape of the drill hole and the structure of the rock.

"The first object, where it cannot be obtained by the drill, is to a large extent governed by putting the charge in tin canisters of the required shape in large drill holes and tamping in with sand, the effects of which are nearly the same as though the holes were drilled the shape of the canisters.

"A break in a straight line is obtained when a horizontal cross section of the charge is elliptical, or nearly so, in shape, the line of break being continuous with the longest diameter. This may be obtained by making the canister of two pieces of sheet tin, with the edges unsoldered and the ends made of paper or cloth, or without the canister by drilling two holes and chipping out the wall between them.

"Two breaks may be made with planes crossing at right angles by making the canister a square prism.

"Much depends on the nature of the explosive used; for dimension stone black powder is nearly always preferred to dynamite, as the former, slow acting like a powerful hydraulic press, tends to split the rock; but the latter, sudden in its action, like a ponderous hammer, tends to shatter the rock.

"Light charges covered with sand are preferable to heavy ones tamped in tight.

"Light charges often repeated are less liable to shatter the rock than one heavy charge."

In the working of any quarry advantage should be taken of the joints and bedding planes as this one thing may make the difference between a quarry worked at a profit and one worked at a loss.

CUTTING AND DRESSING STONE.

While many machines have been invented for cutting and dressing stone still the same slow hand processes that were in use hundreds of years ago are still quite largely used. Large masses of the stone are loosened by means of powder and then these are split into blocks of the required sizes by what is known as the plug and feather method. This method consists in drilling a series of holes about three-fourths of an inch in diameter and a few inches deep along a line where it is desired to split the stone. Into each one of these holes is placed two pieces of soft half-round iron called "feathers" and between these a steel wedge or "plug" is placed. The quarryman then takes a hammer and moves along this line, striking alternately each one of these wedges until the stone splits and falls apart along this line. There is considerable knack in the splitting of various kinds of stone and it consists simply in being able to take advantage of the rift and grain of a stone and it is surprising how readily some persons will work a stone into the desired shape while others can hardly work it into any shape at all.

In some cases stone is cut to the proper sizes in the quarry by means of channelers, steam drills, and portable saws but in most cases marbles, limestones, and sandstones are cut into the desired shapes after leaving the quarry and going to the mill. Usually the stone is taken out of the quarry in large blocks and then taken to the mill where it is usually cut into the required dimension by means of saws and if it is to be carved or polished this is done here and in fact the stone is finished ready for its place in the building.

Most of the cutting to sizes is done by sawing. This sawing is done principally by means of gang saws which consist of a number of toothless blades of soft iron fastened in a frame in a horizontal position and this frame so arranged that it can be moved backward and forward continuously. The stone to be sawed is brought under these saws and the blades set for the required thickness of the stone and then the machine set in motion. The cutting is done principally by sand or some substitute for it which, along with water, is supplied to the saw blades. The water softens the stone, aids in carrying away the dust produced by the cutting of the stone, and in carrying the sand to the saw. The saw may be of almost any length and the frame may contain any number of blades. The blades are usually about one-eighth of an inch in thickness and about four inches wide. In the latest patterns the frames are lowered automatically as the saws cut into the stone.

The rate of cutting by these saws varies with the stone being much faster in some kinds than in others, as for instance the rate for the Tenino sandstone is from one to two feet per hour while in the serpentine, which is a much softer material, at the U. S. quarry the rate is not more than from four to six inches per hour.

The kind of power used for driving these saws varies and may be steam, electricity or water power and in Washington all three are used. Steam however is the one most commonly used but is much more expensive than water power.

Machines of various kinds for planing and dressing marbles have been constructed and they are said to work very satisfactorily, producing a surface equal to a sand rubbed finish and saving much labor and expense in the finishing of marbles. Up to the present time however nothing of this kind is being used in this State.

Lathes of various kinds and sizes are in use in the mills for turning marbles and serpentines. The lathes are used for turning out columns of marble and vases and ornaments of various kinds from marbles and serpentine. These lathes are practically the same as those used for the turning of wood and

iron. After the desired shape has been obtained and while the column or whatever it be is still in the lathe the polisher is brought into use and it is finished before it is removed from the lathe.

For the rubbing of the stone smooth preparatory to polishing the most common contrivance is perhaps what is known as the rubbing bed. This consists of a heavy cast iron plate which revolves in a horizontal plane. The plate is revolved by means of a perpendicular shaft through the center which is geared to the power. This gearing in some cases being above the bed while in others it may be below. Above the revolving bed are a number of fixed arms extending from the center to the outside of the bed and just high enough above it so as not to touch it. The slabs and blocks of marble are placed on this rubbing-bed and these arms prevent their revolving with it when it is put in motion. Onto this plate is then put sand, or some other abrasive, and water. A large number of pieces may be placed on one bed at the same time and rubbed at the same time and rubbed at much less expense than they could be by hand.

PART II.

COAL DEPOSITS OF WASHINGTON.

BY

HENRY LANDES AND C. A. RUDDY.

COAL DEPOSITS OF WASHINGTON.

CHAPTER I.

INTRODUCTION.

GEOGRAPHIC RELATIONS.

The coal fields of Washington, as shown by the accompanying geological map, lie mostly in the western part of the state. They extend in a broken line from the Canadian boundary to the Columbia river, lying on the border between the foot hills of the Cascades and the Puget Sound basin, being entirely within the latter in two or three instances. In most cases the coal fields are within easy reach of tide water and all of them have excellent facilities for transportation. The cost of carrying the coal to market or at least to ports at which shipments may be made by vessel is comparatively small. In some instances special lines of railroad have been constructed for the purpose of connecting the coal fields with the Sound. In other instances the main lines of railway run directly through the coal fields.

In no case has the entire boundary of any coal field been accurately traced, and the exact area of the coal fields of the state is unknown. There are many reasons why detailed mapping of the coal areas has not been done and it will be many years before the exact boundaries of the deposits can be accurately defined. Reliable topographic maps of the coal fields have been prepared in but one or two instances. In addition to this the coal-bearing rocks as a rule are deeply covered, sometimes by an excessive growth of vegetation, sometimes by a thick mantle of glacial material which lies upon them, and in other cases by extensive lava flows which have come down from the Cascades adjoining. Not infrequently also the coal-bearing rocks disappear beneath the later sedimentary rocks which lie conformably upon them. In many instances

the coal-bearing rocks do not appear save where some vigorous stream has cut its way through the thick soil or other overlying material and has disclosed the coal seams along its canyon walls.

A reference to the map above mentioned shows a number of disconnected coal fields, both large and small. The suggestion at once comes to mind that beneath the overlying mantle some of these fields may be connected and therefore of much greater extent than appears at the surface. In other cases it is no doubt true that excessive erosion has removed large portions of what were once larger fields and that we now have only comparatively small isolated remnants remaining.

In addition to the coal fields noted above, which contain seams of coal merchantable in quality and quantity, there are found in the northeastern counties of the state, Chelan, Okanogan, Ferry and Stevens, many small remnants of coal measure areas which contain thin seams of coal. These coal deposits now lie far apart and long continued erosion has reduced them to diminutive sizes. In no case is coal of economic value now found within them.

TOPOGRAPHY.

The physical features of Washington are conspicuous because of their great diversity. The state abounds in alluvial valleys, low plains, high plateaus, deep gorges and lofty mountains. In making a classification of the physical features of the state six distinct provinces are easily recognized. Passing from the Pacific ocean to the eastward these divisions are: Olympic Mountains, Puget Sound Basin, Cascade Mountains, Okanogan Highlands, Columbia Plain, and Blue Mountains.

Of the above topographic regions the coal deposits have to do with two, namely, the Cascade Mountains and the Puget Sound Basin. A varied topography is therefore had passing from the low plains of the coast through plateaus and ridges to the rugged and deeply furrowed mountains. The coal fields of Whatcom county extend from the shores of Puget Sound to within a few miles of the snow-covered slopes of Mt. Baker. The coal fields of King county lie for the most part within the

limits of the Puget Sound Basin but in some cases the eastern limits of the fields extend into the foot hills of the Cascades. In Pierce county the coal fields or the major portion of them at least lie without the realm of the Puget Sound Basin and are within the confines of the Cascade Range. These coal fields, therefore, abound in sharp ridges and deep valleys and for the most part have a truly mountainous character. The Roslyn-Clealum field in Kittitas county lies within the Cascade province and abounds in mountain ridges and deep valleys. The fields of Thurston and Cowlitz counties and the western portion of Lewis county are well within the Puget Sound Basin. They are for that reason regions of low relief, composed of low hills or extended plains, in which the coal-bearing rocks rarely outcrop. In going from the westward toward the eastward in Lewis county the coal deposits attain elevations greater and greater until the last fields are reached when these are found to lie within the heart of the Cascades.

GEOLOGICAL FORMATIONS.

The coal measures of Washington belong to the early part of the Tertiary period or the Eocene epoch. In only a very few instances has the base of the coal measures been found. In the coal fields of Whatcom and Skagit counties the lowest strata of the coal measures lie upon a metamorphic rock, a mica schist of unknown age. At the Blue Canyon and Cokedale mines the largest coal seams lie but a few inches, or at the most but a few feet, above the schists. In general in the different fields the principal seams of coal lie well toward the bottom of the coal series and hence belong to the earlier portion of the epoch. In Washington, during Eocene time, the shore line was somewhere in the vicinity of the eastern border of Puget Sound, and extending southward beyond the present boundary of the state. The Olympic Mountains formed a large island immediately off the coast. The region of the Cascade Mountains was in general one of low relief.

In the northern portion of the state, however, the Cascades were doubtless of considerable height and the streams flowing from them possessed of great strength as shown by the coarse

character of the sediments deposited at that time. The hills were composed of granite rocks as shown by the character of the sediments derived from them. The fossil contents and character of the sediments of the coal fields of Roslyn-Clealum and those of Whatcom and Skagit counties show that these fields represent lake deposits. In the case of the Whatcom coal field the sediments reach an approximate thickness of 20,000 feet and are made up of massive sandstones and coarse conglomerates. In the remaining coal fields as far as known the coal swamps were in estuaries along the shore where brackish water conditions prevailed.

For the most part the coal seams of Washington occur interbedded in a series of light-colored sandstones and shales, with sandstones as the predominating rocks. The latter are usually bluish or grayish in color, but often weather into light buff owing to the oxidation of the iron carbonate which they contain. Carbonaceous matter is distributed in greater or less quantity throughout the rocks of the whole series. Small streaks of coal are found in most of the sandstones. The shales vary in color from light gray to black, according to the amount of carbonaceous matter present. All gradations are found between carbonaceous shale and pure coal. While the number of workable coal veins is small, being perhaps not more than ten or fifteen in any one district, the number of seams of more or less impure coal is very large, considerably over a hundred being known. All the veins thus far discovered which are clean enough to work, and with the coal in sufficient quantity to be of commercial value, are contained in the lowermost three thousand feet of the series. The upper two-thirds of the coal measures have thus far proven barren of workable seams, although rich in disseminated carbon.

During the whole of the long period in which these sediments were being deposited the region was undergoing a gradual but persistent sinking. The evidence of the coal seams in the lowest strata clearly shows that at that period the water at intervals was very shallow, and at the end of the period after sediments nearly two miles deep had been deposited the water still remained at about the same depth, showing that in

the meantime the bottom of the sea had sunk two miles. These nicely adjusted forces of nature permitted the accumulation of a practically unbroken series of sediments throughout the whole period.

Subsidence did not take place at a uniform rate. There were periods during which the process of sedimentation shoaled the waters faster than the sea floor sank, and this continued until the water was shallow enough to support a swamp vegetation, which thereupon spread over the broad lagoons and flourished with great luxuriance. In regard to the climate, Professor F. H. Knowlton* says: "The lower beds, on account of the abundance of ferns, gigantic palms, figs, and a number of genera now found in the West Indies and tropical South America, may be suposed to have enjoyed a much warmer, possibly a subtropical temperature, while the presence of sumacs, chestnuts, birches and sycamores in the upper beds, would seem to indicate an approach to the conditions prevailing at the present day."

Alternating with the periods of coal formation, there were long lapses of time during which the water was too deep to admit of swamp growth. These were the times when subsidence proceeded at a more rapid rate than sedimentation, or at least kept pace with it. Sand and clay were then deposited. The final results of this intermittent, long continued subsidence was that we now have a large number of coal seams and layers of more or less carbonaceous matter interstratified with beds of sandstone and shales.

Since the time of their deposition mountain making forces have been at work throughout the coal measure areas producing in most instances great deformation. The original position of the rocks has wholly changed and for the most part they are tilted at high angles. They have been thrown into extensive folds and as a rule the tops of these folds have been planed off by erosion. In most instances the folding has been accompanied by faulting and the continuity of the coal seams has been broken thereby. As a result of the folding and the

* Geological Atlas of the U. S., Tacoma Folio, U. S. Geological Survey.

faulting of the coal measures in most instances the coal has been greatly crushed and broken. Occasionally when the mechanical action has been greatest a large amount of earthy matter from the roof and floor of the seam has become mixed with the coal so that it is necessary to wash it before it is placed upon the market. As to the extent of deformation it may be said in a general way that it increases in intensity from the western to the eastern borders of the coal fields.

CHAPTER II.

DESCRIPTIONS OF THE COAL FIELDS.

WHATCOM COUNTY.

In the western part of Whatcom county, extending from the foot of Mt. Baker to the coast, there is an area of coal measures embracing over 250 square miles. These coal measures are composed mainly of massive sandstones and conglomerates, with occasional shales, and are exclusively of lake origin. They have a total thickness of many thousands of feet. Within them very much vegetal matter in the form of lignite or coal is to be found, often in irregular masses or pockets, but now and then in a well-defined seam. Occasionally these seams assume dimensions sufficiently large to afford workable coal, and they are then of economic importance. In all cases, as far as known, the beds of coal are not immediately underlaid by clay, but by conglomerate or sandstone, showing that the coal was not formed by the plants which grew upon that particular spot, but rather that it was formed from driftwood. As a result no individual seam of coal can be expected to extend throughout the coal basin, or even over a large part of it, but it is more local in its extent. It is also true that a coal seam will show considerable variability in thickness when followed in different directions.

Since their deposition the coal measures have been greatly folded and the strata are now inclined at high angles. Erosion has removed large portions of them, as may be seen in the wide valleys of the Nooksack and its tributaries, in the basin of Lake Whatcom, and elsewhere. In the eastern and central parts of the Whatcom coal field the strata outcrop everywhere and the coal beds may be easily found, but in the western part of the coal field the rocks pass under a heavy mantle of glacial drift and may only be studied or prospected by diamond drilling.

In the coal fields of Whatcom county, veins of workable coal have been found at a number of places. In some instances extensive mines have been opened and large quantities of coal produced. In a general way the coal may be said to improve in quality from west to east, as one passes from the region of least folded rocks to those that have suffered the greatest deformation. The coal vein now being developed on Cornell creek, within six miles of Mt. Baker, is of a better quality than any other so far found in the county.

The Bellingham bay coal vein is the uppermost one in the coal measures of Whatcom county. It is 14 feet thick, a lignite in quality, and was extensively worked 20 years ago. Its outcrop is north through the middle of the city of Whatcom and thence north-westerly, dipping west and southwest from 8 to 10 degrees.

Blue Canyon Field.

Blue Canyon Mine.—This mine is located on the southeastern shore of Lake Whatcom, on the line of the Whatcom branch of the Northern Pacific Railway. The vein of coal that is being worked varies much in thickness, but averages about 7 feet. It lies at the very base of the coal measures, being separated from the mica schist lying below by a layer of conglomerate which varies from six inches to three feet in thickness. Where the conglomerate is thinnest the coal vein is greatly broken and shattered, and is occasionally faulted. Lying as it does between the massive sandstones above and the metamorphic rocks below, the vein has suffered greatly in the deformation of the coal measures. The vein pitches to the northwestward at an angle of 50 to 60 degrees.

The Blue Canyon mine has been in operation for a number of years, but has done little more than supply the demand of the cities and towns of Bellingham Bay and thereabouts. The coal is very desirable for steaming and for domestic purposes. In 1901 the output of the mine was 8,200 tons, and 1902 it was 6,010 tons.

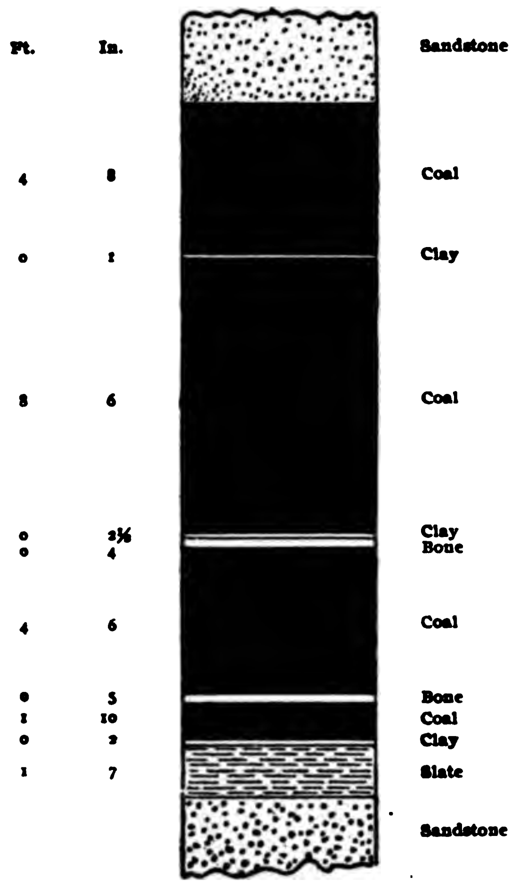


Fig. 1. Cross-section of Blue Canyon vein.

CORNELL CREEK FIELD.

On Cornell creek, a tributary of the North Fork of the Nooksack river, coal measures appear which have a thickness of not less than 20,000 feet. They are composed mainly of massive sandstone and conglomerate and are clearly continuations of the strata of the Blue Canyon field. In the coal measures are a number of veins of coal, one of them having a thickness varying from 2 to 14 feet. At one place in the south end of T. 29 N., R. 6 E., about $10,000 has been spent

in prospecting this coal vein, and 1,200 feet of tunnels have been driven. The vein has a strike about east and west and a dip of 70 degrees to the north. The coal is a semi-anthracite, or sometimes even an anthracite in character and contains from 78 to 92 per cent. in fixed carbon. While the coal vein is quite regular the coal itself is very much broken and in using it it may be necessary to feed it into the furnaces in the form of powder or else to make it into briquettes.

SKAGIT COUNTY.

In the western half of Skagit county coal measures outcrop at a number of places. Surrounding these outcrops, as a rule, there are small coal basins, which seemingly have never been connected but have always been separated one from another. In the northwestern part of the county the large coal field of Whatcom county extends into Skagit for a little way. A mile west of Thornwood, on Samish river, there is an outcrop of coal where a little development work has been done. Immediately east of Montborne there is a small area of coal measures with a few coal outcrops. Near Cokedale and Hamilton there is in each case a coal measure area in which well known veins of coal occur.

The coal-bearing rocks above mentioned are composed essentially of shale, sandstone, and conglomerate, with very much irregularly embedded vegetal matter in the form of lignite or coal. These deposits have been made in lakes which were enclosed in basins of metamorphic rocks, mainly schists and slates. After the lake sediments accumulated to a great thickness they were folded to such an extent that the strata are now often inclined at high angles. Since the disappearance of the lakes the lacustrine sediments have been largely removed by erosion, and it is possible that the removal has been so great in the cases of the smaller lake deposits that some of these may have been entirely eroded.

COKEDALE FIELD.

Cokedale Mine.—At the town of Cokedale a coal mine has been in operation for a number of years. The mine is located

at the extreme northern limit of the coal basin, the lowest vein of coal being but a few feet from the schist which lies below. The coal measures of Cokedale outcrop along the northern boundaries of the district, but for the most part they

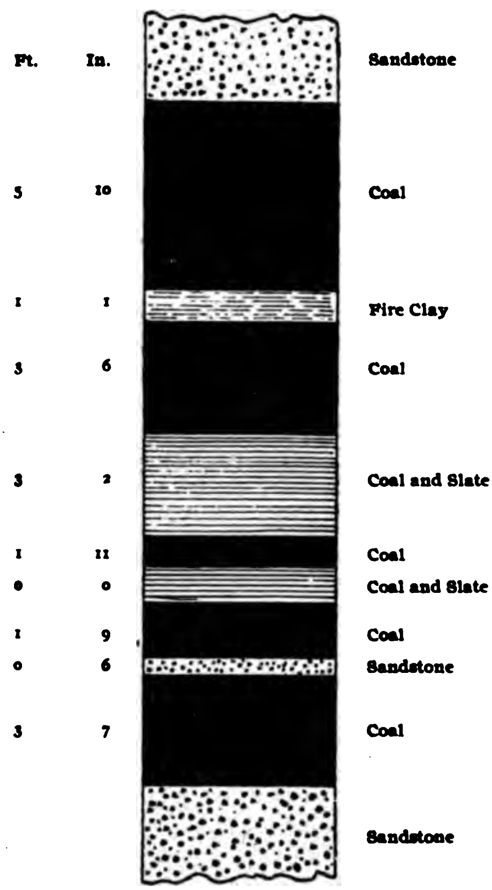


Fig. 2. Cross-section of Cokedale vein.

are covered by the alluvial deposits of the Skagit river. The district is not believed to be a large one, extending from Cokedale southward to the Skagit, and in an east and west direction from near Lyman to a point a little way beyond Sedro-Wooley.

At the Cokedale mine three veins of coal are found, viz.; the north or Klondike vein, the middle vein, and the south vein. The north vein is the lowest one in the series and has a thickness varying from 10 to 25 feet; the middle vein lies 140 feet above the north vein, stratigraphically, and has a thickness of from 4 to 8 feet, with an average of 6 feet; the south vein, lying 40 feet above the middle vein, has a thickness varying from 6 inches to 2½ feet. The north and middle veins only are worked at the present time.

The Cokedale coal veins at their outcrops stand about vertical, but in the lower mine workings they dip slightly to the southward. In the deformation of the coal measures the coal was so greatly broken that in mining it it is obtained only in small pieces, and never in large lumps. It is a good coking coal, and a large part of it is made into coke. The coal is all passed through washers after leaving the mine; the coarser part is then used for steaming and domestic purposes, while the finer part is taken directly to the coke ovens near by. Forty ovens are now in place. They are of the beehive pattern, each having a capacity of five tons. In 1901 the output of the Cokedale mine consisted of 12,643 tons of coal and 5,806 tons of coke, and in 1902 it consisted of 19,017 tons of coal and 601 tons of coke.

Hamilton Field.

A few miles east of the Cokedale district, and near the town of Hamilton, is a region of coal-bearing rocks known as the Hamilton field. This district lies chiefly between Cumberland and Day creeks, and extends from the Skagit river to the neighborhood of Deer creek. The rock outcrops of the Cokedale and Hamilton districts are separated by the broad alluvial plain of the Skagit, and it is not known at the present time whether the coal-bearing rocks extend from one district to the other.

At several places in the Hamilton district coal veins of commercial importance are known to outcrop. Upon some of these veins considerable development work has been done, and in times past some coal has been mined and sold. The

coal is of good quality, and of a variety that may be made into coke. As a rule the coal veins lie in such a position that they may be worked very readily.

On the property of the Skagit Cumberland Coal Company and on the lands of Mr. J. J. Conner, near the mouth of Cumberland creek, there are a number of outcropping coal veins. The first of these is located on the bank of Cumberland creek, not far from the contact of the coal measures with the underlying mica schist. This vein of coal has a strike of south 43 degrees east, and a southwest pitch of 55 degrees. It lies between sandstone walls, and has a thickness of about

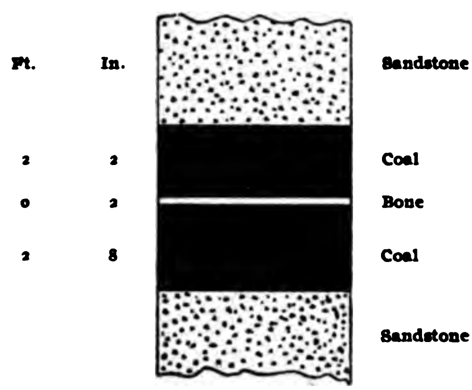


Fig. 3. Cross-section of Hamilton vein.

7 feet of clean coal. About a hundred feet stratigraphically above the vein just mentioned, is a second coal seam having approximately the same dip and strike, with a thickness of over 5 feet. Above the outcrop of the number two vein, at varying heights on the mountain side, are outcrops of several other veins of coal with thicknesses ranging from a few inches to 4 feet.

Toward the southern part of the Hamilton field, in the region about Day lake, coal outcrops at a number of places. In a few instances some development work has been done. In sections 13 and 24, T. 34 N., R. 6 E., the coal veins have a thickness varying from 8 to 12 feet.

KING COUNTY.

Newcastle–Issaquah Field.

Newcastle and Coal Creek Mines.—Newcastle is one of the oldest coal mining towns in the state, the mines having been in continuous operation for the last forty years. It is located about ten miles southeast of Seattle and about three miles from the eastern shore of Lake Washington. Most of the mining has been done in sections 25, 26, and 27, T. 24 N., R. 5 E. The mines are reached from Seattle by a branch of the Columbia and Puget Sound railroad, which runs around the southern end of the lake, by way of Renton. Both mines and railroad are the property of the Pacific Coast Company. The Newcastle mines are very favorably situated with regard to transportation facilities, being only about seventeen miles by rail from tide water.

The first discoveries of coal in this field were made in the valley of Coal creek, a small stream flowing into Lake Washington, and along which all the principal openings are located. The coal measures outcrop in the bed of the stream and on both sides of the valley. The prevailing rock is a fine grained light colored sandstone, having the bleached appearance characteristic of rocks associated with coal. Beds of shale all more or less darkened by carbonaceous matter occur interstratified with the sandstones. Immediately underlying the coal measures and at a distance below the lowest coal vein of not more than 150 feet is an older formation whose relation to the coal measures is not definitely known. It seems to be composed largely of volcanic rock, but in the vicinity of Newcastle contains scattered through it fossil leaves and stems. In the vicinity of Issaquah, along the valley of Tibbett's creek, a similar formation is seen underlying the coal measures but at this point the older rocks are evidently of true volcanic origin, being continuous with the mass of pyroxene andesite which forms Squak mountain nearby. To the northward of Newcastle the coal measures pass under a thick mantle of glacial drift which covers the whole surface of the country thereabouts. The structure of the field about Newcastle is that of a simple monocline, the strata dipping

northward at an angle of about 40 degrees. The strike of the measures is nearly due east and west.

The coal at Newcastle has been mined from a number of openings at various times. The last mine was opened in 1895, but it has not been working for the past two years. There are still about 100,000 tons of coal in this mine, and this will be taken out at some time in the future. At the present time active operations are confined to the new Coal Creek mine, located about one mile east of the town of Newcastle. Within this mine, and exposed along the creek, there are nine distinct seams of coal, but only four of them are being worked at the present time. The mine is opened by a double-track tunnel 5,800 feet long and 7 feet by 14 feet, in cross-section. Electric lighting and haulage are employed. It is about four years since work was begun on the main tunnel of the Coal Creek mine and the coal has been shipped from it for the last three years.

The main tunnel follows the course of the Bagley vein (known also as No. 1 and No. 2) for about 3,000 feet, or to a point where the Bagley vein splits into two parts. The tunnel then swings to the upper or northern bench and follows along that for the remainder of the way. The total width of the Bagley vein before it splits is 22 feet. The northern or upper bench, after splitting, is about 7 feet wide and the lower bench 12 feet wide. From the end of the main tunnel a crosscut has been driven southward to the lower bench of the Bagley vein, and gangways driven along the vein both east and west. Nearly all the coal in the lower Bagley bench between the crosscut and the mouth of the tunnel has been taken out. The crosscut tunnel has been extended northward to veins No. 3 and No. 4, both of which are being worked. The lower workings are connected underground with an upper tunnel 1800 feet long, which opens on the hillside above the town of Coal Creek. The coal is mined by the breast and pillar system where the roof is bad and by the panel system where the roof is good. In the breast and pillar system chutes ten feet wide are driven upward from the main gangway every forty feet. At a height of twenty-five feet they are widened

out to twenty or twenty-five feet with pillars between them twenty-five or thirty feet wide. The breasts are carried upward to the next gangway above or to the surface, or as near to the surface as it is safe to go. Crosscuts four feet wide are driven through the pillars every sixty feet to allow of a circulation of air through all the workings. Each pillar is then split from the bottom upward by a ten-foot chute. This is carried upward to the top and the narrow strip six or seven feet wide on each side drawn from the top downward. In this manner all the coal is extracted except a row of stump pillars left to prevent the gangways from caving. All the workings from which the coal has been extracted are allowed to cave. In the panel system breasts about fifty feet wide are driven and pillars thirty feet wide left between them. This system can only be employed when the roof is very solid. In veins No. 1, No. 2 and No. 3 the breast and pillar system is the only one that can be employed on account of the shaky condition of the roof. The panel system is employed in vein No. 4, which has a much more solid roof than the other. Modifications of the two systems are sometimes employed to suit the varying circumstances. On the character of the roof depends to a considerable extent the cost of mining.

A slope was sunk on a vein near the mouth of the new tunnel a number of years ago and a large amount of coal was taken out of it, but the mine caught fire about eight years ago and it was therefore abandoned and allowed to fill with water up to the water level. This vein splits in going westward and has been worked in the Newcastle mine as two distinct veins, separated from each other by about sixty feet of rock. In the new Coal Creek mine the same vein is known as No. 3, and when followed eastward it attains a width of about forty-two feet between walls, but of this width not more than two or three feet is clean coal. The remainder of it is composed of thin bands of clay, bone, and coal, alternating with one another.

In the old Newcastle mine the veins when followed westward were found to be involved in a fault which threw them

about one hundred feet to the northward. Another fault occurs between the Newcastle and Coal Creek workings which has served a useful purpose in preventing the spread of fire and water from one set of workings to the other. No faults of any importance have been encountered in the Coal Creek mine. The strike of the veins is nearly the same in all parts of the mine. The dip varies from 38° to 40°, but is usually about the latter. The coal from Newcastle has been tilted upward from its original horizontal position without undergoing any internal movement within the seams, and therefore has not

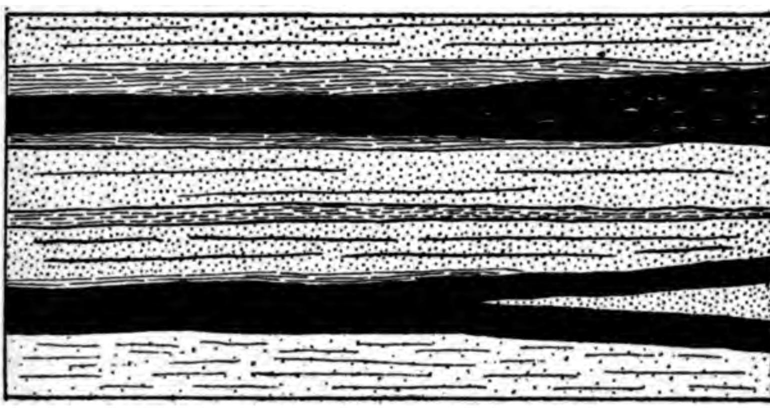


Fig 4. Cross-section in Coal Creek Mine, near Newcastle, showing splitting of vein.

lost its lignite character. It is a hard, compact coal with a bright lustre. It is used almost exclusively for steaming and for domestic purposes. None of the veins are of solid, clean coal, but all contain streaks of more or less bony coal, which must be hand picked and washed.

It is not customary for the veins in the Newcastle field to be followed until they pinch out. Usually when followed any considerable distance the coal forms a relatively small proportion of the total contents of the vein. Some of the largest veins known to occur in the coal measures are not worked because they have too high a percentage of ash. A layer of dirty coal or bone overhanging a workable seam detracts consid-

erably from its value on account of the difficulty of holding up such a roof. Sandstones make the best roof and impure coal and bone make the poorest. Care is taken in the mines not to leave very much coal behind in the abandoned workings. When brought into contact with air the coal left behind gradually heats and finally takes fire, owing to the oxidition of its volatile constituents. Some disastrous fires have arisen from this cause, notably the one started eight years ago in veins No. 1 and No. 2, which is still burning.

The outside equipment of the Coal Creek mine consists of a modern washing plant having a capacity of about 500 tons per day of ten hours. All of the coal from the mine is sent to the washers. About 1000 tons of coal are required to make 600 tons of clean, marketable coal. The coal cars are dumped onto screens which allow the fine coal to pass through them. The coarse coal goes onto sorting tables, where the bone and rock are picked out by hand. The fine coal goes to the washing machines. A strong current of water is forced in from below and the coal and dirt are kept in constant motion by revolving arms and by the upward current of water. The coal being lighter than the dirt accumulates at the top and is washed over the sides. The dirt is drawn off from the bottom at intervals of about ten minutes. The coal as it passes from the washing machine falls into revolving screens, which separate it into two grades, nut coal and pea coal. Nut coal is put on the market for domestic use. The pea coal is used for steam making and a large amount of it is used under the company's own boilers. A 265 H. P. engine and dynamo generate power to run the electric motor and furnish lights for the main tunnel. A subsidiary engine and dynamo furnish lights for the two towns of Coal Creek and Newcastle. Other engines run the fans and the washing plant.

The mines about Newcastle have produced in round numbers about five million tons of coal. The output for the year 1901 was 130,957 tons, and for the year 1902, 140,841 tons.

Issaquah Mines.—These mines are located two or three miles from the southern end of Lake Sammamish, at the northern base of Squak mountain, about six miles east of Newcastle.

Pacific Railway, which runs around the northern end of Lake Washington. The coal is a lignite similar to that of Newcastle and is used entirely for domestic purposes and for generating steam. It is sold on the market under the name of Grand Ridge coal, the name being taken from one of the company's mines on the eastern end of the property. Most of the coal has been taken out of section 33, T. 24 N., R. 6 E., but in some of the gangways the coal has been followed westward into section 32, the 800 foot level of No. 4 vein having been driven more than half way across that section.

Squak mountain forms the western part of a great mass of eruptive rock which is cut fairly in two by Issaquah creek, a They are reached by the Snoqualmie branch of the Northern comparatively insignificant stream which flows northward into Lake Sammamish. About two miles south of the town of Issaquah the stream leaves the narrow gorge by which it flows through the mountain and enters a wide, level valley which extends northward to Lake Sammamish. The coal measures lie upon the northern flank of Squak mountain and dip to the northward at an angle varying from twenty to forty degrees. The mines are opened by slopes and water level tunnels driven on the western edge of the valley at the base of the mountain.

There are five principal veins in the Issaquah series, varying in width from five to eighteen feet. The dip of the veins has been found to increase with depth; at the surface it is about twenty degrees, but in the lowest workings it is thirty-eight or forty degrees. Operations are now conducted on veins No. 4 and No. 5. No. 5 vein is worked by a water level tunnel which runs westward into the mountain. The coal is now nearly all worked out above this level. During the past year an upper tunnel was run on the vein for a distance of about two hundred feet and the coal sent down to the washers over a 1200-foot incline. In this upper tunnel the vein is five feet in thickness and contains two seams of clay having thicknesses of four inches and two inches respectively. Vein No. 1 was worked by a slope 800 feet long, from which gangways were driven east and west from the 400-foot and 800-foot levels. This vein has a total width of eighteen feet, but there is only

eight feet of it that is clean enough to work. The remainder of the vein contains thin streaks of coal and bone interstratified. Vein No. 4 is the principal producer at the present time. A rock tunnel was driven northward from the bottom of the slope on the 800-foot level of No. 1 vein to No. 4, and a large amount of coal has been taken out of No. 4 by this opening, and it is still producing a little coal. A new slope was sunk on No. 4 vein about a year and a half ago. It is now down a distance of twelve hundred feet and it is proposed to sink it still deeper. This vein has been worked extensively to the westward, having been followed for two miles on the 800-foot level,

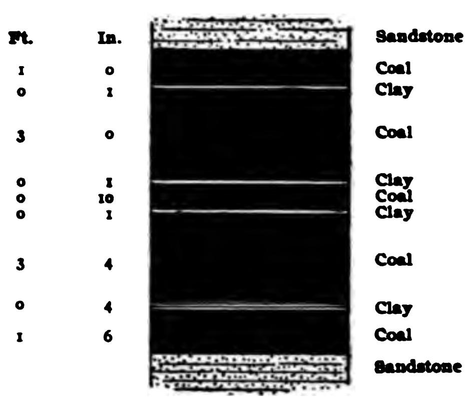


Fig. 5. Cross-section of No. 4 vein, Issaquah, in East gangway, 1200-foot level.

or beyond Tibbett's creek. It is said to become too bony in that direction to be worked with profit. This vein is only four and a half feet thick at the bottom of the slope, but when followed westward it widens to twelve feet, and at the point where work was stopped at the east end it is nine feet wide. On the 1200-foot level the west gangway is now in about 2000 feet. At the face of the gangway the vein contains seven feet six inches of coal, with only one or two small partings of clay. At the face of the 1200-foot level east the vein showed nine feet ten inches of good coal, with very little clay.

Thus far every attempt to drive the gangways eastward

under the valley of Issaquah creek has met with failure. The floor of the valley is composed of glacial sand and gravel to a depth of at least four or five hundred feet, and wherever this has been tapped by the gangways the miners have been driven out by floods of water and sand, and strong bulkheads of tim- and cement have had to be erected to prevent the mine being flooded. The last encounter of this kind was in the east gangway of the 1200-foot level of No. 4 vein. Water and gravel had previously been encountered in the 800-foot level of both No. 1 and No. 4. It was hoped that at the 1200-foot level it would be possible to get under the valley, but in the workings sand, gravel and clay of the old valley were again encountered and the miners were driven out.

The bottom of the ancient valley is considerably below sea level and it probably was occupied in pre-glacial times by an arm of Puget Sound, which at that time covered a much more extended area than at present. Lake Washington at that time constituted a part of the Sound, and beyond this lake a long arm of the sea occupied the basin of Lake Sammamish as far south as Issaquah. The debris left by the ice on its retreat has greatly modified the old topography and has completely filled up many of the old waterways. When the glacial material was encountered in the Issaquah mine it was found to be composed of clay, sand and gravel, with many large boulders scattered through it. It also contains a large amount of water under sufficient pressure to flood all of the tunnels which have been thus far driven into it.

The structure of the field about Issaquah is very similar to that about Newcastle. The general strike of the coal measures is N. 80° W., or within four degrees of that of Newcastle. This strike would carry the Issaquah veins to Newcastle, and it is probable that the veins of the two places, if not identical, are at least in the same geological horizon. There is a vein at Issaquah sometimes called the Bagley vein, but it is by no means certain that it is the same as the Newcastle vein of the same name. The gap between the two localities, Newcastle and Issaquah, has lately been bridged to some extent by the workings of the Consolidated Coal Company's mine on Tibbett's creek,

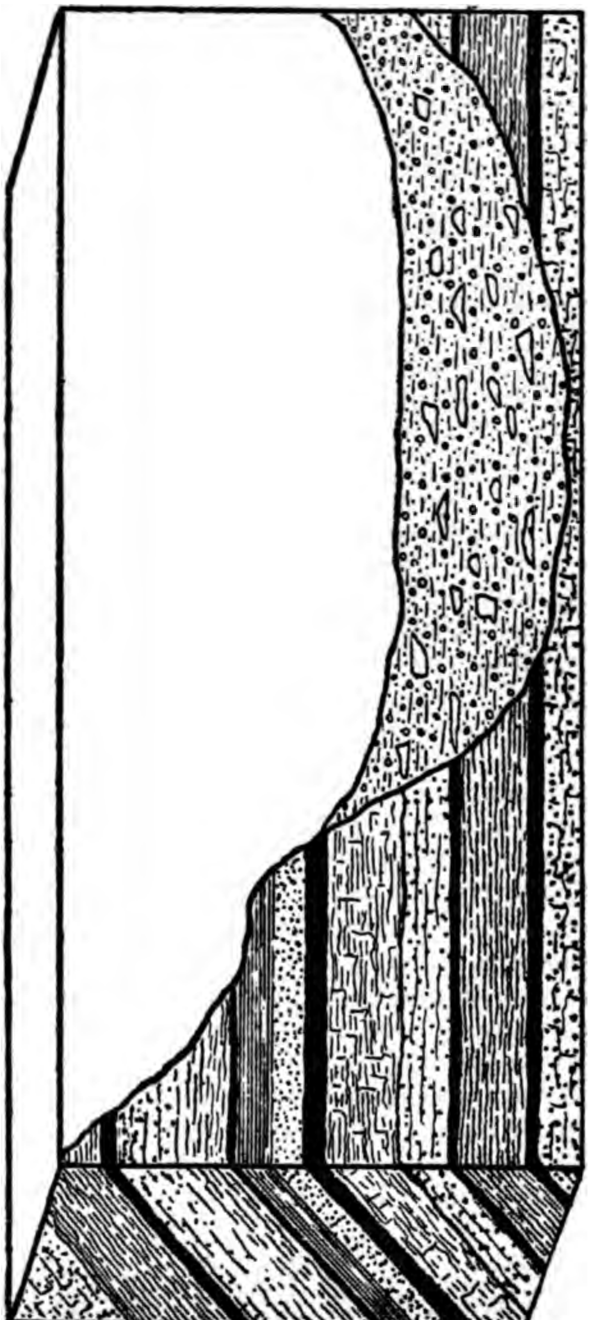


Fig. 6. Illustrating pre-glacial erosion in Issaquah Coal Field.

described below. It serves to further strengthen the theory that the coal field is continuous between the two places.

About two miles east of Issaquah the strike of the coal measures swings around to the northward and the veins dip westward. The Issaquah Coal Company has opened up some veins in Sec. 26, T. 24 N., R. 6 E., at a place known as Grand Ridge. Two slopes and a tunnel have been driven here, but no work is being done at present. It is the intention of the company to work out all of this coal by way of the Issaquah openings as soon as they find a way of tunneling under the Issaquah valley successfully. The veins at Grand Ridge are underlaid at a depth of about 250 feet by eruptive rocks, which may be seen outcropping along the railway. It is not likely that these rocks have been intruded into the coal measures, but probably constitute an older formation upon which the coal measures were laid down. Two veins have been worked at Grand Ridge, the upper one being four feet and the lower one seven feet in thickness. They pitch N. 68° W. at an angle of 25 or 30 degrees. The coal seams in this mine are underlaid with clay and considerable trouble has been experienced because of the clay floor squeezing up into the tunnels.

The Issaquah mines (formerly known as the Gilman mines) were opened by the Issaquah Coal and Iron Company in 1887. The holdings of the company embrace a tract of land five miles long by one and a quarter miles wide. Up to the present time about three hundred and twenty acres of coal have been worked out, and the mines have yielded about 1,500,000 tons of coal. The output for 1901 was 121,829 tons, and for 1902 it was 117,184 tons.

The Consolidated Coal Company of Seattle is opening a new mine on Tibbet's creek, between Issaquah and Newcastle. Two tunnels have been driven on the east side of the creek in the southern part of section 32. One tunnel is about 90 feet long, and the other 175 feet long, both on the same vein. This vein measures eight feet in width and contains only one two-inch streak of clay. It is probably the same vein as No. 6 of the Issaquah Coal Company, whose western gangways on the veins lying above No. 6 have passed under Tibbett's creek not

very far north of the Consolidated workings. The general strike of the veins on Tibbett's creek is the same as at Newcastle and Issaquah, and the dip is to the north. As soon as facilities are arranged the coal will be hauled from the mine to the washery, a distance of three and a half miles, by an electric motor. The washery and bunkers will be situated on the railroad, about a mile and a half below the town of Issaquah, where the company has acquired a site for its plant.

Renton–Cedar River Field.

The depression occupied by Lake Washington is continued southward first as Black river valley, and then as White river valley. Less than a mile from where Black river leaves Lake Washington, Cedar river enters the former from the eastward, flowing through a narrow, steep-sided valley for a number of miles and entering the broader valley at the town of Renton. Between the valleys of Cedar river and White river there is a plateau which from the surface indications seems to be composed entirely of glacial drift. It has an average elevation of about four hundred feet above the level of the bordering valleys. Along the steep-sided northern and western edges of this plateau, especially near the town of Renton, the coal measures outcrop from beneath the covering of glacial drift. Seven or eight miles farther up the valley of Cedar river the coal-bearing rocks are again exposed, where the Cedar mountain mine has been opened.

Renton Mine.—The Renton coal mine is located on the hill back of the town of Renton, at the southern end of Lake Washington, near the point where Cedar river enters the northern end of White river valley. The main tunnel of the mine runs in an easterly direction into the hillside about half a mile south of the town and not more than thirty or forty feet above the level floor of the valley.

Coal has been mined in the vicinity of Renton for the last thirty years. The old Talbot mine, located south of the present workings, was worked out many years ago and abandoned. The present mine is located between the old Talbot workings and Cedar river valley. While three veins are known to occur

here, only two are being worked at the present time. These veins are known as No. 2 and No. 3, the former overlying the latter at a distance across the strata of about eighty-seven feet. The veins dip eastward at an angle varying from fifteen degrees at the surface to ten degrees at the bottom of the slope. The strike of the veins in the present mine is nearly due north and south. In the south workings of the Talbot mine the measures swing around to the westward, the change in direction being much more pronounced in the upper levels of the mine than in the lower ones. To the northward of the main slope in the present mine the veins have been followed

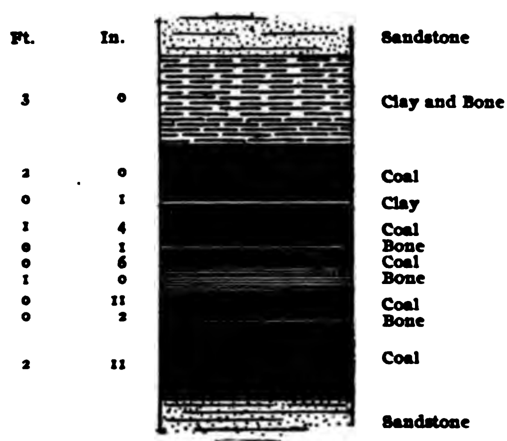


Fig. 7. Cross-section of vein No. 3, Renton Mine.

until the surface gravels were reached in the Cedar river valley, a distance of about 2500 feet. The veins do not outcrop anywhere on the surface, but are covered to a depth of twenty or thirty feet by glacial gravel.

In the development of the mine most of the work done thus far has been on No. 3 vein. On this vein a slope 1100 feet long has been sunk, through which until recently all of the coal mined was brought to the surface. The coal is now all taken out through a tunnel 400 feet long which enters the hill a little above the valley level and connects with the slope. Four levels have been driven north and south from the slope. Four

rock tunnel connects veins No. 2 and No. 3. No. 2 has only recently been opened, but it is rapidly being put in shape for extensive working.

No. 3 vein is about nine feet thick, nearly eight feet of which is good coal. In the northern part of the mine there is a three-foot layer of bone, shale and clay overlying the coal. These materials scale off and do not make a good roof. They are in turn overlaid by a thick bed of soft, white, incoherent sandstone. To the southward the bone, shale and clay thin out until the sandstone lies directly upon the coal. No. 2 is a sixteen-foot vein, only the upper seven feet of which is worked. The roof of this vein for several feet overhead is a hard shale which usually makes a good roof, but occasionally scales off. Everywhere in this roof of shale are found stumps of trees standing upright, with their roots still embedded in the ancient soil. Tree trunks lying prostrate also occur, some of them forty or more feet long. The soil on which this forest grew lies directly upon the topmost layer of coal. The soft vein matter which forms the floor of the workings on No. 2 vein keeps squeezing up so that the floor is continually rising and has to be lowered occasionally. There is another vein still higher in the series, known as No. 1. It outcrops on the hillside above No. 2, but not much known as to its value, since it has never been prospected to any extent.

A number of irregularities in the strata have been encountered in the mine. On the north side of the main slope a fault occurs, having a throw varying from fifty feet in the upper levels to 80 feet in the lowest level. This fault is a simple break in the strata whereby the rocks have been pushed past each other so that they overlap for a distance of forty or fifty feet. In the south level a similar fault occurs with the strata overlapping. This fault has a throw of forty-five feet. Apparently the large block forming the center of the mine has been forced down by lateral pressure and the two outer sides forced upwards on it. There are a number of minor irregularities in the vein but none of them have interfered seriously with the process of mining. A disturbance in the strata also occurs in the valley of Cedar river. This is shown by the fact

that extensive prospecting on the north side of the valley has failed to find the coal where it should occur if a break in the strata or a sudden change in the strike had not taken place.

The sandstone which forms the greater body of the enclosing rock is very soft and friable. When thrown on the dump it quickly crumbles into loose sand. Considerable trouble has been experienced on account of the walls squeezing together thereby necessitating constant retimbering. This crushing movement is due chiefly to the flatness of the vein and the unconsolidated character of the overlying rocks.

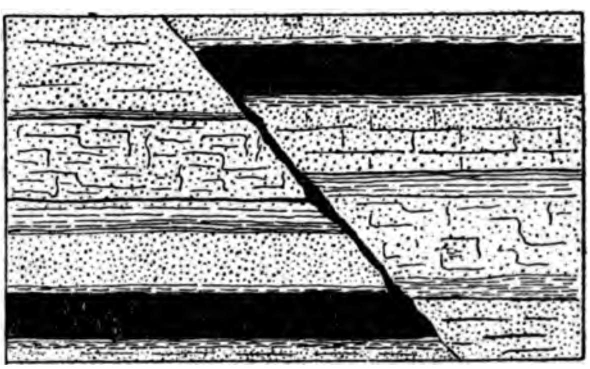


Fig. 8. Reverse Fault, No. 3 Vein, Renton Mine.

The Renton coal is a black lignite. At the present time about 400 tons per day are being taken out. The coal is hand picked and washed with Howe washers before being placed upon the market. The mine is now the property of the Seattle Electric Company, who use about half of the entire output in their own furnaces and the rest is placed upon the market as a domestic and steam coal. The total output of the mine for 1901 was 72,865 tons, and for 1902, 104,071 tons.

Cedar Mountain Mine.—Cedar Mountain is a station on the Columbia and Puget Sound Railway about twenty miles southeast of Seattle, and six miles east of Renton. Formerly it was an important coal shipping point but of late years it

has not been very active. At this place several seams of coal may be seen outcropping in the railroad cuts and in the bed of Cedar river. The most important vein is known as No. 1, which varies from eleven to fifteen feet in thickness, practically all of which is clean coal. This is the vein that was worked in the old Colman mine on both sides of Cedar river for a number of years and was a great producer in its day. The Colman mine was worked by a slope from which gangways were driven both north and south on vein No. 1. The north workings were continued until the gangways ran into an old pre-glacial stream channel which cut out the coal in that direction. Southward of the main slope the gangways were extended until they encountered a fault of unknown extent, beyond which the vein seemed to be lost. Surface prospecting for a long time failed to discover what had become of the lost vein and after all the coal had been worked out north of the fault the mine was closed down in 1892.

In 1898 the Cedar Mountain Coal Company opened a new mine on a vein known as No. 2, lying below No. 1. No. 2 is nine feet thick but contains a seam of dirt a foot or more in width which must be mined with the coal. Until a washing plant is built this coal cannot compete in the market with the washed coal of other mines. Nevertheless from No. 2 there was shipped 13,500 tons of coal in 1901, but active operations ceased in the spring of 1902 because of a change of ownership of the mine. The coal from No. 1 vein never required washing but was shipped just as it came from the mine.

More thorough prospecting has lately uncovered No. 1 vein on the other side of the fault from where it was abandoned in 1892. The surface of the country away from the river is heavily covered with brush and fallen timber and the solid rock lies beneath a mantle of gravel, sand, and soil many feet in thickness. This accounts for the delay in finding the vein. The coal is a hard black lignite and is a good domestic and steam coal. It contains a high per centage of moisture and volatile hydrocarbons but burns freely and when it was on the market was popular as a domestic coal.

The Cedar Mountain Coal Company own all of section thirty except the south half of the south half. They also own nearly all of section nineteen south of Cedar river. Several other veins of coal occur on their property, but beyond the fact of their existence little is known of them. It is probable, however, that some of them will yet prove to be valuable.

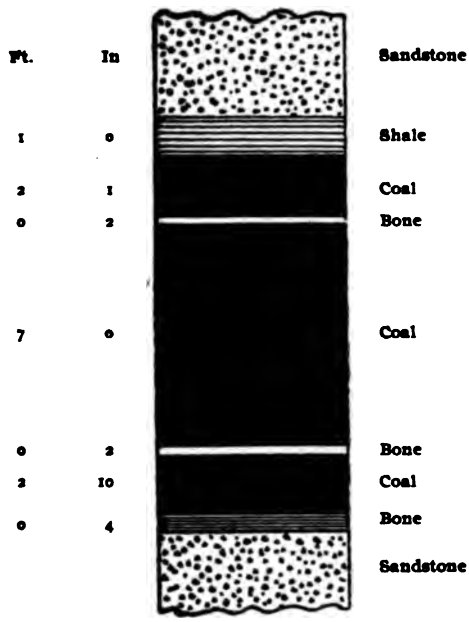


Fig. 9. Cross-section of vein, Cedar Mountain Mine.

NIBLOCK FIELD.

The Niblock Coal Company own lands to the extent of 2,160 acres lying about two miles south of Snoqualmie Falls. A short branch railroad has just been completed to the mine from the Snoqualmie branch of the Northern Pacific Railway, connecting with the main line about half a mile above the Falls. The Green River Northern branch of the Northern Pacific Railway is also being extended into the same region and will make its terminus in the Niblock property. This latter road is being built primarily to take out the splendid

timber which covers all that region but it will also afford an outlet to the southward for the Niblock coal. The distance by rail to tide water in either direction is about fifty miles. The region in which the coal occurs is about nine miles east of Issaquah and well within the foot hills of the Cascade range. The strata are considerably more disturbed and broken than are those of Issaquah and Newcastle. The coal has lost its lignite character and has become a soft bituminous coking coal. The region is one of somewhat rugged topography. The coal lies upon the western side of a ridge about a thousand feet high which parallels Snoqualmie valley for several miles above the falls, and which is composed in large part of eruptive rocks. To the west and south of the Falls there

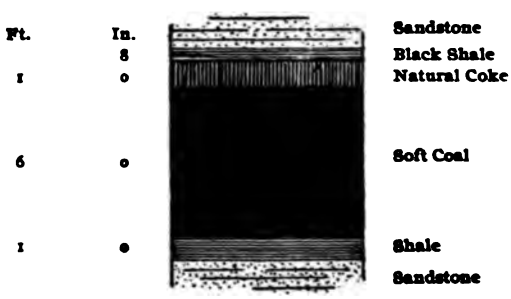


Fig. 10. Cross-section of No. 3 Vein, No. 8 Tunnel, Niblock Mine.

are a number of ridges and isolated hills composed of eruptive rocks which form conspicuous features of the landscape. Their relation in age to the coal measures has not been satisfactorily determined, but in the Niblock field it is evident that, in part at least, they are older than the coal measures.

There are eight veins of coal known to occur within the field, but only two of them have been prospected to any great extent. These are known in the series as No. 3 and No. 5. Vein No. 3 varies in width from seven to nine feet. It is a first class coking and blacksmithing coal, and has been extensively prospected by tunnels and test pits, the longest tunnel being about 700 feet. Vein No. 5 consists of two benches of coal, each about six feet thick and separated from each

other by eighteen inches of bone and shal.e The upper bench is rather soft and dirty but the lower bench is good commercial coal. It consists of three or four layers separated from each other by thin partings of clay. Both veins are enclosed in sandstone walls.

The strike of the coal measures is north 12 degrees west and the dip is to the southwestward, at an angle of from forty-five to sixty degrees. The veins in places are pockety, i. e., they widen and contract quite rapidly. This in itself does not involve much loss of coal, since what is lost in one place is gained in another, but during the process of pinching in which the walls were slid along one another a considerable amount of the wall rock was mixed in with the coal thereby rendering some of it too dirty to be of any value.

The development work on the Niblock property has extended over a period of ten years or more and consists of several tunnels and a large number of test pits. About $25,000 in all has been spent in putting the mine in shape to ship coal. The lowest tunnel, through which it is intended to work the mine, has been driven a distance of four or five hundred feet. An inclined tramway leads from the mine mouth to the washing plant and bunkers situated on the railway track. A coking plant is also contemplated to treat the coal from vein No. 3. Some of the other veins will probably be found clean enough to work when they are developed. The region is all very heavily covered with thick underbrush making it difficult to explore, and this accounts in part for the slowness with which the mines are being opened.

Raging River Field.

The Raging River field lies a few miles to the southwest of the Niblock field and embraces a considerable portion of T. 23 N. R. 7 E., on the western side of Raging river. No mines have ever been developed in this district and little is known of the extent of the coal. Surface croppings have been found in many places over an area of eight or ten square miles, and in several instances prospect tunnels have been driven as far as 200 feet. The coal for the most part seems to be considerably

broken up and has been rendered bituminous. An eight-foot vein occurs on section 8, while the croppings of seven or eight veins have been found on sections 16 and 21. On section 26 much tunnel work has been done in times past but little of value has been found.

Fig. 11. Cross-section of vein, Raging River Field, Secs. 25 and 26, T. 23 N. R. R. 7 E.

In the region south of Raging river coal has been found north of Walsh lake in section four. In section 3 a coal vein shows in a deep gulch along the Columbia and Puget Sound Railroad, about half a mile above Sherwood Station. This vein stands perpendicular, with a north and south strike. A short tunnel has been driven on the vein but the coal did not prove to be of any value. The region is one of low relief and the surface is nearly everywhere covered by glacial drift. It is probable that the coal measures underlie all of it. From the occasional outcrops found it is evident that the rocks are thrown into a series of north and south folds which involve the Niblock and Raging river fields.

Green River Field.

This coal field is located about thirty miles southeast of Seattle, on the line of the Columbia & Puget Sound Railway. It includes most of T. 21 N. Ranges 6 and 7 E., with portions of the adjoining townships north and south. Green river flows along the southeastern edge of the field in a deep canyon cut in the coal bearing rocks. Away from the river the surface of the country is covered with glacial drift, in some places to a considerable depth, but usually with only a thin coating. Along the railroad between Black Diamond and Frank-

lin the coal bearing rocks appear in the cuts. They are mostly sandstones, weathered into light buff or brown tints by the oxidation of the iron. A large number of shale beds occur, more or less darkened by the carbonaceous matter which they contain, and associated with them are about forty beds of coal, bone and black shale, varying in width from a few inches to forty feet or more. Only three or four of the coal seams are clean enough to work. The McKay or Black Diamond vein is by far the most important of all, and varies in width from four feet six inches to seven feet, practically all of which is clean coal. The McKay vein has produced nearly all of the coal mined in the district. At the present time it is the only vein worked outside of the Franklin mine, where two other veins are being worked, viz., the Gem and the Fulton or No. 12 vein. The Fulton vein is about forty feet wide between walls but contains many streaks of bone, and only a small part of it can be worked. The Gem vein, lying above the McKay and Fulton veins, is three feet wide, without any partings of bone or clay in it. Other veins occur above and below these but it is not believed that any of them are clean enough to work.

The rocks of the district have been thrown into broad open irregular folds trending in a general way northeast and southwest and pitching to the southwest. Black Diamond is on the western edge of the field and Franklin on the eastern edge. The two mines of the Black Diamond Coal Company, No. 11 and No. 14, are located on the western side of an anticline and the Lawson mine and the old Light Ash mine are on the corresponding eastern side. Between Lawson and Franklin the strata form a basin on the eastern rim of which the Franklin mines are opened, the veins dipping westward at steep angles. The intermediate mines, Black Diamond No. 12, and Franklin No. 7, are located upon the northern rim of the basin.

Coal was first discovered along Green river in 1880 and the Black Diamond and Franklin collieries were opened two or three years later. At the present time there are seven mines in operation and the total output is not far from 1,500

tons per day. The coal is a high grade semi-bitumionous steam coal and used very largely for locomotives and steamers. It leaves only a small quantity of ash, with no clinkers. In composition it occupies an intermediate position between the lignites of Renton and Newcastle and the bituminous coking coal of the Wilkeson-Carbonado district.

Black Diamond Mines.—These mines, two in number, are located on the western edge of the field, in sections 11 and 14. The old slope, No. 14, is sunk on the Black Diamond vein in section 14. Three levels have been driven on the vein in both directions, from the main slope. From the third level a second slope has been sunk and two levels driven from it. The Black Diamond vein is the only one worked in this mine. It varies in width from five feet ten inches to six feet three inches. The coal is so clean that it does not require washing but is placed on the market just as it comes from the mine. The levels driven southward from the slopes ran into broken ground in the vicinity of Lake Jones and the vein was not followed any further in that direction. In the northern part of section 14 three minor faults were encountered in the workings. The third one near the line between mines No. 11 and No. 14, was not penetrated but was left to serve as a wall between the two sets of workings. In the north end of mine No. 14, the strike of the vein is almost due north and south, but when followed southward it swings to the eastward almost at right angles. The nature of the disturbance in the strata at Lake Jones is not definitely known, but it is supposed that there is a sharp synclinal axis accompanied by faulting. Whether or not the Black Diamond vein and the McKay vein are identical is still open to dispute. They are generally believed to be the same but until that part of the field around Lake Jones is explored underground the question can not be settled.

No.11 mine is opened by a slope one mile north of No. 14. There are two veins in the No. 11 mine, one known as the little vein and the other as the Black Diamond vein. The little vein lies above the Black Diamond vein about eighteen or twenty feet. It is rather dirty and is not being worked at

present because the coal would have to be washed. The main slope, 1,600 feet long, is sunk on the little vein. Another slope 400 feet long goes down to the fourth level, which is the deepest in the mine. From the two slopes gangways have been driven north and south, the south gangway going as far as the fault, which separates No. 11 from No. 14. Northward the vein has been followed over 5,000 feet. It goes first north and then swings to the eastward into section 12 where it has an almost east and west strike.

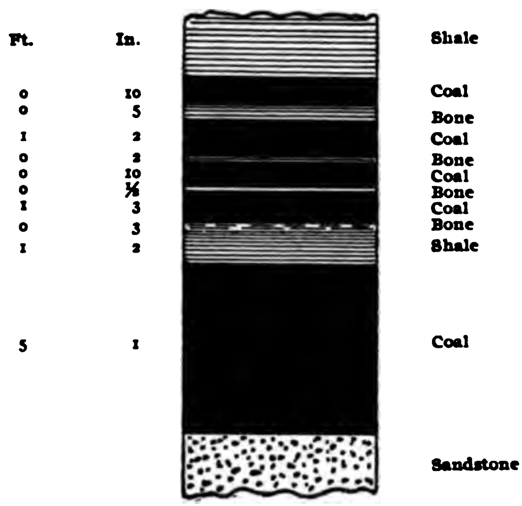


Fig. 12. Cross section of Black Diamond vein, Black Diamond Mine.

Black Diamond mine No. 12 is on the opposite side of the anticline from the two other mines of the company. It is opened by a slope on the McKay vein near the eastern boundary of section 12. It is not being worked at the present time.

The Black Diamond mines are owned by the Black Diamond Coal Company. They produced in 1901, 227,000 tons and in 1902, 258,996 tons.

Franklin Mines.—The Franklin mines are owned by the Pacific Coast Company. The property of this company includes four sections of land directly east of the Black Diamond mines. At Franklin three veins are being worked, the

McKay, the Fulton or No. 12, and the Gem. The first two are operated by means of a slope, and the Gem by means of a tunnel, which is over a mile long. The opening of the Gem tunnel is in section 19, and it runs northward through most of section 18. A shaft is being sunk near the mouth of the Gem tunnel to open up the McKay vein, which it is expected will be found at a depth of about 1,350 feet. The McKay vein was formerly worked by way of the main slope of the old mine as far down as the seventh level, but at the time of the big explosion, several years ago, the mine took fire and had to be flooded.

Fig. 13. Cross-section of Gem vein, Franklin Mine.

The three Franklin mines, No. 1, No. 7, and Gem, produced in 1901, 129,171 tons, and in 1902, 190,080 tons.

Lawson Mine.—The Lawson mine is located on the western rim of the McKay basin, in the western part of section 13. It is the northward continuation of the old Light Ash mine. A slope 1,400 feet in length has been sunk on the McKay vein which is the only one worked in this mine. The vein averages in thickness about four feet four inches of clean coal. This mine makes considerable gas, and the safety lamps are used in nearly all the underground workings. The coal that is to be reached from this slope covers the space between the Light Ash mine on the south and Black Diamond No. 12 on the north. It is estimated that there are as yet 5,000,000 tons of coal within reaching distance of the Lawson slope. The output of the Lawson mine in 1901 was 97,329 tons, and in 1902, 107,750 tons.

Kummer Mine.—This mine, belonging to the Denny Clay Company, is located at Kummer, on Green river,

toward the western border of this field. Kummer is reached by a branch line of the Columbia & Puget Sound Railway. The mine is not worked extensively, the output being limited to the coal used in the works of the Denny Clay Company in Seattle. The number of tons mined in 1902 was 10,044.

Ravensdale Mines.—The Ravensdale or Leary mines are located on the Palmer cut-off in section 36, T. 22 N., R. 6 E.

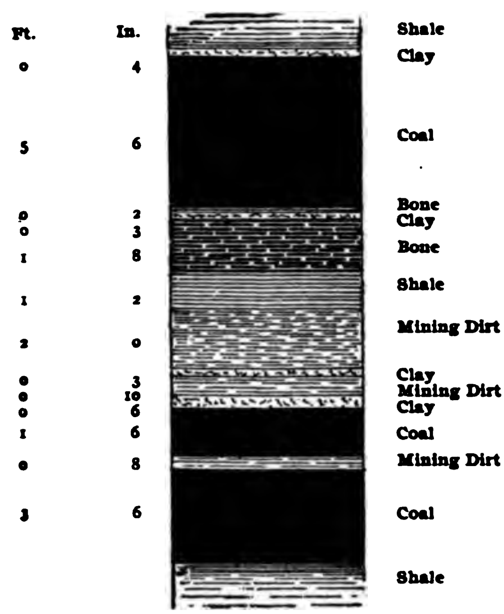


Fig. 14. Cross-section of No. 4 vein, East side, Ravensdale Mine.

They are the property of the Seattle & San Francisco Railway Company. The mines are located on a series of veins which outcrop about a mile and a half north of the most northern mines of the Black Diamond Company. Between Ravensdale and Black Diamond there are no rock outcrops, since the country is flat and swampy and is covered with glacial drift to an unknown depth. It seems probable that the Ravensdale veins occur considerable higher in the series than those of Black Diamond and Franklin. The end of the north gangways of Black Diamond mine No. 11 shows the strata dipping

northward, and at Ravensdale, a mile and a half further north, they are dipping in the same direction at angles varying from twenty-five to forty-five degrees. Unless there should be a fold in the intervening space, which is not impossible, the Ravensdale veins must be assigned to a considerably higher place in the coal-bearing series than those of Black Diamond.

Six veins of workable size occur in the Ravensdale series, the two extreme ones being about eighteen hundred feet apart, measured across the strata. Only three veins, No. 4, No. 5,

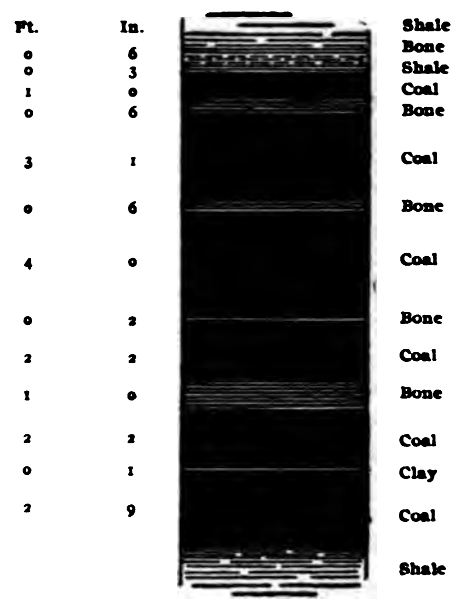


Fig. 15. Cross-section of No. 5 vein, east side, Ravensdale Mine.

and No. 9 are being worked at the present time. They outcrop on both sides of a small creek, and tunnels have been driven east and west on the outcrops. Those on the west side are being the most actively developed.

Vein No. 3 has been opened by tunnels on both sides of the creek. It contains five benches of coal varying in width from nine to twenty-nine inches and separated one from another by clay partings from two to six inches, in thickness. The vein contains too large a proportion of waste and is not

being worked. No 4 vein is over eighteen feet wide between walls and contains three benches of coal, with widths of one foot six inches, three feet six inches, and five feet six inches respectively. Tunnels have been driven on No. 4 vein on both sides of the creek, but only the west tunnel is now being worked. Vein No. 5 is over eighteen feet wide, fifteen feet of which is coal. The vein contains several partings of bone from an inch to a foot in width. It is worked on the west side of the creek by a tunnel now in a distance of 1,500 feet and a slope about 420 feet long. The next workable vein above No. 5 is known as No. 9. It contains a bench of about three feet of good coal in the middle of the vein. It is opened by tunnels on both sides of the creek. Two other veins, No. 1 and No. 2, have been uncovered but neither of them are considered clean enough to work.

An electric locomotive is used in hauling the coal from the mine mouth to the washery. All of the coal is hand picked and washed before being placed upon the market. The company has a well equipped washery capable of handling about four hundred tons per day. The coal is used for steam and domestic purposes. The output of the Ravensdale mine in 1901 was 63,578 tons, and in 1902 71,426 tons.

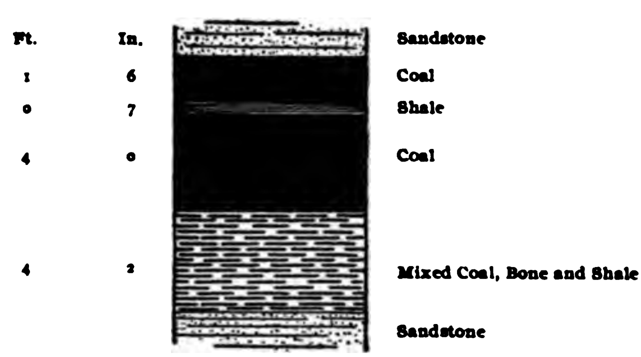


Fig. 16. Cross-section of vein, Kangley Mine. (W. J. Wood.)

Kangley Mine.—The Kangley mine has been shut down for the last four years, but for a number of years previous to that

date it was a good producer. It is situated on the Green River Northern branch of the Northern Pacific Railway, about four miles north of Palmer. It was worked by a slope twenty-three hundred feet long, and gangways three-fourths of a mile long. There was only one vein worked and this was so badly faulted that the mine was finally abandoned. The pitch of the vein is to the eastward at an angle of 35 to 40 degrees. The coal produced was bituminous and of good quality.

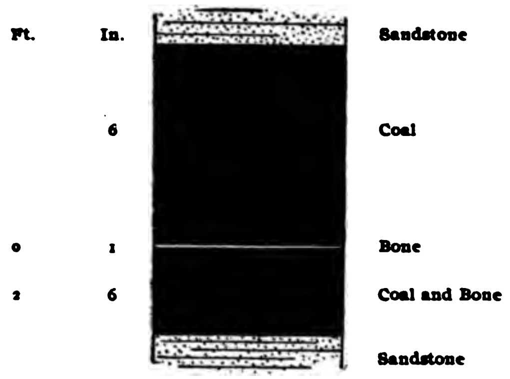


Fig. 17. Cross-section of vein, Alta Mine. (W. J. Wood.)

Alta Mine.—The Alta mine was worked on the extension of the Kangley vein, in section 36, but it was abandoned when a fault was encountered.

Durham Mine.—The Durham mine, belonging to Balfour, Guthrie & Company, is located on the railroad half way between Kangley and Palmer. It has never been worked to any great extent.

Coal veins are known to outcrop on Sugar Loaf Mountain, in section 34. Three veins have been uncovered and a tunnel fifty feet long driven on one of them. The title to the property is now in dispute and until it is settled not much development work will be done. The veins strike nearly east and west and dip to the northward at an angle of about 23 degrees.

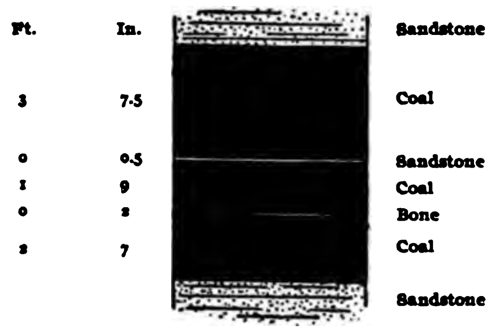


Fig. 18. Cross-section of vein near Sugar Loaf Mt. in Sec. 34, T. 22 N. R. 7 E.

Palmer Junction marks the eastern limit of the coal-bearing rocks in the Green River valley. East of this point the river flows in a deep valley or gorge cut entirely in eruptive rocks. A number of veins outcrop in the region south of Palmer in sections 14, 15, 22, 23 and 24, as well as at the Gibbon mine in section 16, and at the Carbon and Sunset mines in sections 21 and 28. A railroad spur two or three miles long runs to the Pocahontas mine, which is located in section 24. Along the line of this railroad a number of coal seams appear in the cuts, some of them ten or twelve feet wide.

Pocahontas Mine.—At the Pocahontas mine a rock tunnel twelve hundred feet long has been driven to crosscut the veins at right angles. Three veins were encountered in the tunnel and there are yet three or four lying above these which the tunnel will cut through when extended. The strike of the coal measures is north and south, and the veins dip eastward into the mountain side at an angle of thirty-five degrees. The coal is bituminous and of a good furnace quality. A great deal of gas was encountered in driving the tunnel and all the workings must be well ventilated. The bunker site is situated at the end of the railway track, about half a mile west of the mine mouth. A two-foot vein of dirty coal outcrops near the bunker site, dipping westward at a steep angle. At the mine half a mile east the veins dip in the opposite direction, showing that the arch of an anticline is located in

the intervening space. Work has been suspended for the present at the Pocahontas mine but it is expected that operations will be renewed early in the future.

Gibbons Mine.—The Gibbons mine (formerly the Occidental mine) is situated in the southeast quarter of section 16, about a mile from Palmer. A short spur connects it with the main line of the Northern Pacific Railway. It is situated at the eastern base of Lizard mountain and forms part of the Lizard mountain coal basin. The veins dip to the southeast at an angle of about 45 degrees. The strike is fairly regular but the veins are greatly crushed and brecciated. In some places large angular blocks of white sandstone are imbedded in the vein matter. Ten veins are known to occur on the

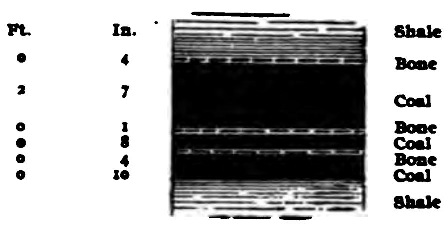


Fig. 19. Cross-section of No. 6 vein, Gibbons Mine.

property and of these eight have been worked more or less. A tunnel has been driven on vein No. 3 and the other veins have been worked by way of this tunnel. The veins are rather more broken up than is usual in the mines of this district and the irregularities have interferred seriously with the progress of development. The output is now from sixty to seventy tons per day. The coal is not washed but is shipped just as it comes from the mine. Considerable gas has been met with in some of the workings. All the development thus far has been above water level. The output in 1902 was 3,225 tons.

On section 21, which is the next section south of the one on which the Gibbons mine is located, the Carbon Coal Company opened a mine six or seven years ago. It was operated for three years and has been closed down since that time. The

mine is opened at the southeast base of Lizard mountain, the mouth of the tunnel being within a few hundred feet of the main line of the Northern Pacific Railway. A small washing plant and bunkers were installed alongside the railroad track. It is possible that this mine may again be put in operation sometime in the future.

There is a group of several mines around Cumberland station, all located in section 28. Of these the Sunset mine, located in the southern part of the section, is the only one in operation at the present time. Two veins are being worked in the Sunset mine, each of them containing about three feet

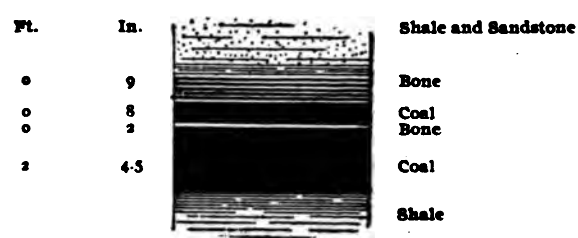


Fig. 20. Cross-section of No. 1 vein, Sunset Mine.

of coal. Vein No. 2 lies about two hundred and fifty feet above No. 1. The Navy mine is worked out, and the Eureka mine has been closed down for a long time.

PIERCE COUNTY.

CARBON RIVER FIELD.

This field lies about midway between the city of Tacoma and Mount Rainier. All of the producing mines are in the northern part of the field and not far from the main line of the Northern Pacific Railway. A branch of the Northern Pacific Railway enters the district by way of South Prairie Junction and reaches all of the mines in this field. Another branch leaves the main line at Crocker Junction and runs up Carbon river canyon to the Carbonado mines. The field includes all the mines centered about the towns of Burnett, Wilkeson, Carbonado, Melmont, and Fairfax. All the mines are located

along Carbon river and its tributaries, South Prairie creek, Gale creek and Evans creek. Carbon river, which derives its name from the numerous outcroppings of coal along its course, flows for about eight miles through the district. Between Melmont and Carbonado and for two miles below the latter town the river flows through a deep and precipitous canyon, the upper part of which is cut in a hard eruptive rock and the lower part in the coal measures. The topography of the district is somewhat varied, being more rugged in the southern part where it approaches the mountains. Gale creek and South Prairie creek flow through shallow valleys cut for the most part in the coal measures. Away from the streams the surface is covered with glacial drift varying in depth from a few feet to nearly a thousand feet. Old stream channels filled with drift have been encountered in several places in the underground workings of the mines. Numerous potholes, some of them of great size, indent the surface of the region. The whole country was formerly entirely covered with a heavy growth of timber but in the vicinity of the older mines most of it has been removed for mine purposes. In the southern part much splendid timber still remains and forms a valuable asset to the resources of the district.

In the Carbon river canyon a section of the coal measures is exposed five thousand feet in thickness which dips to the westward at steep angles. All the workable seams are contained in the lowermost three thousand feet. Other sections of the coal measures are shown along Gale, South Prairie and Evans creeks.

The coal measures have been thrown into a series of north and south folds which extend from one end of the field to the other with scarcely any change in direction. In the northern end of the field there is one main anticline known as the Wilkeson arch. From Carbonado southward a number of smaller folds occur and the rocks are considerably more distorted. More or less connection may be traced between the veins of Burnett, Wilkeson and Carbonado but in the newer mines of Melmont and about Fairfax the relation between the veins of

the different mines is not so well known. In every mine in the district from half a dozen to a dozen veins of more or less value are know to occur.

The coal of the Carbon river district is a bituminous coking and steam coal. A considerable amount of it is also used for gas making and blacksmithing purposes. Not all the coal makes good coke, but that of Wilkeson and Fairfax is used very largely for this purpose. It is probable that as soon as the new mines of Melmont, Montezuma and Hillsboro get their coke ovens built the output of coke from the district will be more than doubled. In the southern end of the district, owing to the disturbed condition of the strata, the coal is richer in fixed carbon and its coking qualities are better. At the present time the total output of the district is about two thousand tons per day, about one-fourth of which is made into coke.

Burnett Mines.—These mines are opened along South Prairie creek in the most northerly part of the Carbon River field, the present opening being not more than half a mile from the main line of the Northern Pacific railway. The property belongs to the South Prairie Coal Company and consists of eleven hundred acres in sections 16, 21, and 22, T. 19 N. R. 6 E. The mines were opened twenty-one years ago by Mr. C. H. Burnett, the present superintendent and general manager. Up to the present time over one million tons of coal have been taken out and it is estimated that there are still nearly five million tons available. Operations have been conducted on both slopes of the great Wilkeson anticline which in this part of the field has a strike of N. 25 degrees W. and pitches to the northward. At the present time all the coal is being taken from two veins on the eastern dip. The good coal has not been found to extend northward more than a third of a mile beyond the town of Burnett. The coal measures in that direction pass under a heavy mantle of drift and the northward dip of the strata carry the veins downward to a considerable depth. Above the town the strata are exposed along both sides of the creek for several miles. Form-

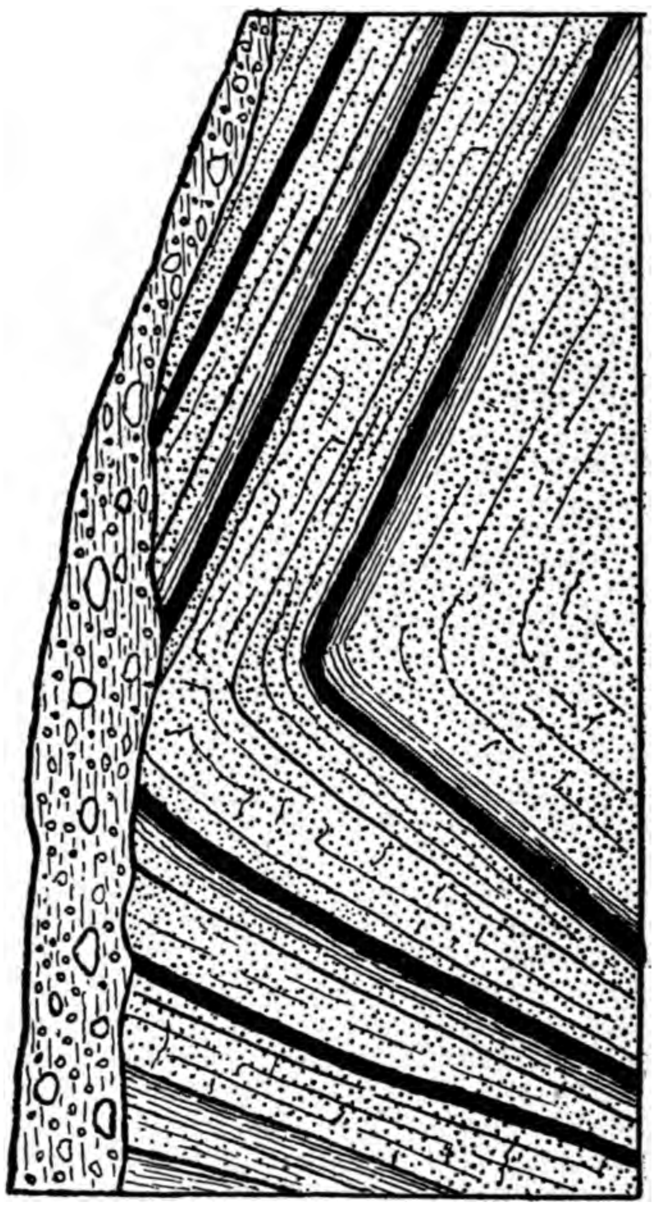


Fig. 21. Cross-section of the Coal Measures at Burnett.

erly there were large sandstone quarries located just above Burnett but they have not been working for several years.

The present Burnett mine is worked by means of a slope sunk in vein No. 1 on the eastern dip. It runs diagonally down the pitch of the vein to a vertical depth of six hundred and twenty-five feet. From a point on the slope four hundred feet from the entrance a rock tunnel was driven across the strata to veins No. 4 and No. 5. No. 5 vein does not outcrop on the surface and its existence was not suspected until it was encountered in the tunnel. Veins No. 2 and No. 3 were opened by water level tunnels on the western side of the anticline, No. 2 being followed for twenty-four hundred feet. On the western dip the veins stand at an angle of from fifty to eighty degrees, but on the eastern dip they are not so

Fig. 22. Cross-section of No. 4 vein, Burnett Mine.

steep. It is probable that vein No. 1 on the east side is identical with vein No. 2 on the west side, and that No. 4 corresponds to No. 3. No. 4 and No. 5 are the only veins being worked at the present time. No. 5 shows three feet eight inches of clear coal and has been opened up by a gangway over four hundred feet long. A chute was driven upwards on No. 5 from the main gangway and at a height of four hundred and eighty-five feet the vein turned over and started down on the western dip, having reached the top of the fold. The turn was made without breaking the vein or the enclosing rocks to any appreciable extent.

On vein No. 1 the gangways were driven a distance of ten thousand feet, the southern end of the gangway being directly

under the stone quarry at Wilkeson. Vein No. 4 contains three feet of coal with a clay band in the middle which varies in thickness from two to twelve inches. Old No. 1 is not being worked at the present time. It contains three and a half feet of coal. There is still a large amount of coal blocked out in the north gangway which is in a distance of fifteen hundred feet. On No. 4 the gangways have been driven southward eight thousand feet and there is still nine hundred feet to be driven in that direction.

Three pumps of a total capacity of three million gallons per day are employed to keep the mine free of water. All the coal is washed before being placed upon the market. A large amount of it is used in gas manufacture and for steam-making in the various cities about Puget Sound. The output of the mine in 1901 was 77,255 tons and in 1902, 32,003 tons.

Fig. 23. Cross-section of No. 5 vein, Burnett Mine.

Wilkeson Mine.—The Wilkeson mine is one of the most extensively developed properties in the Carbon River field. The underground workings extend in an approximately north and south direction through sections 27 and 34, T. 19 N. R. 6 E. and section 3, T. 18 N. R. 6 E. The main opening to the mine is on Gale creek, in section 27. All the present workings are above water level and it will be many years before sinking operations will become necessary. The mine is opened on both sides of the main Wilkeson arch, which is the chief structural feature of the locality. A water level tunnel driven on vein No. 2 on the western dip penetrates southward for two and a quarter miles. A rock tunnel driven eastward across the strata from the main tunnel has opened up three

workable veins on the eastern side of the anticline, known respectively as No. 1, No. 2, and No. 7. Vein No. 3 lies still further eastward and will be found by extending the cross-cut tunnel in that direction. Four veins have been worked on the western dip, corresponding to those on the eastern dip. In the southern part of section 34 the gangways on the western dip encountered an overthrust fault which had thrown the measures to the westward four hundred feet. The veins were again picked up by a rock tunnel driven westward from the point where the veins were lost, and after being found they were followed southward until at the present time the furthest gangway is in the southwestern part of section 3. Besides the crosscut tunnel which leads to the veins on the eastern dip near the line between sections 27 and 34, another tunnel, a mile further south, has been driven from the west to the east veins to afford an outlet to the eastern veins at that point.

Vein No. 2 on the eastern dip has a gangway from the north opening two thousand feet long. The vein varies in width from four to eight feet and dips at an angle of sixty degrees. Vein No. 1 in the same set of workings contains about five feet of coal and is worked from a gangway sixteen hundred feet long. Not much coal is being taken out of No. 1 in this gangway at the present time. Where No. 1 is opened in the southern end of section 34 it contains two benches of coal each three feet wide and separated by a fourteen inch band of bone. Vein No. 7 is about seven feet nine inches wide. It contains two benches of coal separated by a parting of bone nine inches thick. The lower bench contains five feet of the best coal in the mine. The gangway on No. 7 is thirty-eight hundred feet long.

The mines are worked by the chute and pillar system, as being best suited to the conditions of roof and coal, Narrow chutes are driven upward from the main gangway and crosscuts driven from one chute to the ather every forty or fifty feet. The pillars are pulled beginning at the top and working downward. A row of stump pillars thirty feet

thick is left to protect the gangways. The coal is washed by means of Forrester jig washers which have been found to work very satisfactorily. Water for the washery is brought from Gale creek through a flume half a mile long. Two small steam locomotives are used to haul the coal from the mine, one of them working on the east side and the other on the west side.

The output of the mine averages five hundred tons per day, three hundred tons of which is made into coke and the remainder sold as steam and domestic coal. All the coal is coking and the product of the different veins is mixed indiscriminately before being sent to the coke ovens. There are one hundred ovens in constant operation. The mine was opened in 1879 and since that time has produced about 1,000,000 tons. The output in 1901 was 125,028 tons, and in 1902, 106,896 tons.

Gale Creek Mine.—The Gale Creek mine is located on the northeast quarter of section 28, T. 19 N. R. 6 E., on the northern outskirts of the town of Wilkeson. The principal opening is by a slope on vein No. 1, four hundred feet long, from the bottom of which a gangway has been driven northward on the vein six hundred and fifty feet. This vein contains three feet nine inches of clean coal. It is not a coking coal but is sold for steam and gas making. Vein No. 2 is not being worked at the present time. It was opened by a tunnel three hundred feet long driven across the strata to encounter it, after which a gangway five hundred and seventy feet long was driven south of the vein, and another shorter one north from the main tunnel. Vein No. 2 averages three feet eight inches of good coal. The opening on the Queen vein is about a quarter of a mile east of the opening above mentioned, and on the opposite hill from the Wilkeson mine opening. A tunnel runs into the hillside nine hundred feet along the vein, which averages about four and a half feet in width. The present output of the two veins, No. 1 and the Queen, is about one hundred and fifty tons per day. The coal is not washed but goes directly to the bunkers. New bunkers are being

erected, and it is expected that a washing plant will be added to the equipment in the near future.

In addition to the veins which are being worked a number of others are known to occur on the property. Between No. 1 and No. 2 there is a six-foot vein and a three-foot vein, neither of which, however, yield coal clean enough to put on the market without washing. A three and a half foot vein occurs about two hundred feet above No. 1 and there is a six-foot vein below the Queen vein. Several large veins of fire clay are interbedded with the coal which may prove to be valuable.

All the veins which have been opened in this quarter section dip westward at an angle of about seventy-five degrees. They occur on the western side of the Wilkeson anticline and lie higher in the series than the veins worked at the Wilkeson mine. They are probably the same as those worked at Burnett. From the Gale Creek mine in 1901 18,900 tons of coal were mined. The total output in 1902 was 29,640 tons.

Carbonado Mine.—This mine is, next to Roslyn, the largest in the state and when worked to its full capacity has a daily output of from twelve hundred to fifteen hundred tons. At the present time, owing to several causes, chief of which is the substitution of crude oil for coal in the locomotives of the California railways, the output is not more than four hundred tons per day. Heretofore all the coal which the mine produced was shipped to California and no attempt was made to find a market for it in this state, but at the present time much of the output is consumed in the home market. It is a first-class steam coal and is used very largely in locomotives. It gives an intense heat, cokes only to a slight extent in the furnace and leaves only a small amount of ash. When it becomes better known probably a large amount of it will be used for domestic purposes. Analyses of the coal from the different veins show a slight variation, especially in the percentage of ash, but they are all bituminous non-coking coals. The coal has none of the scaly appearance of the Fairfax and Melmont coal, probably due to the fact that it has not been

subjected to the same degree of crushing. A number of tests have been made of the coking qualities of the various veins but only with indifferent success. Thus far no good coking coal has been found in the Carbonado workings, but the Wilkeson coking veins have been followed in that company's gangways as far as the Carbonado company's line, so it is probable that coking veins will yet be found on the Carbonado property. A rock tunnel begun twenty years ago is now being extended eastward from Carbon river canyon, across the strata to find the Wilkeson vein. It is now in a distance of over 3,000 feet.

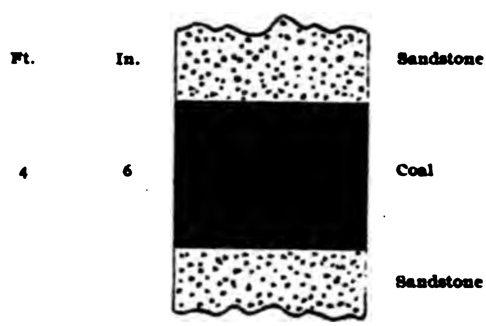


Fig. 24. Cross-section of vein, Carbonado Mine.

Carbon river at Carbonado flows through a steep sided canyon about 350 feet deep. The town is situated above the canyon on comparatively level ground. The mine openings are all at the bottom of the canyon. Operations have been conducted from a number of openings on both sides of the river. At the present time most of the coal is being taken from the Wingate vein on the west side of the river. A slope 450 feet long has been sunk on this vein, and gangways driven southward for about 9,000 feet. The vein is from five to seven feet in thickness and produces an excellent quality of coal. It has been mined extensively for many years and still contains a very large quantity of good coal within reaching distance. Two duplex Dow pumps of 1,000,000 gallons

per day capacity each, keep the mine clear of water. A small steam locomotive works along the main gangway at the bottom of the slope. In order to prevent too much smoke coke is used for fuel. On the same side of the river the Miller vein, which lies 600 feet above the Wingate vein, has been worked extensively in the past, but is not worked at the present time. Both of these veins have been involved in a fault which has thrown them about 1,000 feet out of line. The Wingate has been picked up on the northern side of the fault and followed for about a mile on the east side of the river, when the gangway turned back on its course and ran into some broken ground at which point the vein was abandoned. It is probable that if followed a little further it would again become regular. Two other veins, known as No. 4 and No. 9, have in the past been worked extensively on the west side of the river but the coal in them has deteriorated in quality and they are now abandoned. On the east side a rock tunnel crosscuts a number of veins of more or less value. On one of them, known as No. 1, a gangway has been driven southward over 1,900 feet and a considerable quantity of coal is being produced from it. This vein averages about nine feet in thickness, and is nearly all clean coal. It has been tested for coke making but has not proven altogether suitable. A smaller vein, No. 2, lies about 100 feet below No. 1. Where it is crosscut in the main tunnel it shows about twenty-eight inches of good clean coal next to the hanging wall, and a thick seam of dirty coal along the foot-wall. About 1,000 feet in on the No. 1 gangway a crosscut was driven to No. 2, and it was there found to be thirty-eight inches thick. A chute was driven upward 1,050 feet to the surface on No. 2, in the expectation that it would prove to be the same vein which outcrops along the canyon side just below the old wagon road. However, No. 2 proved to be not the same but a higher vein. The vein which is shown in the outcrop contains about six feet of good clean coal, and now that it has been definitely located in the underground workings develop-

ment will soon be commenced upon it. The south end of the gangway on vein No. 1 is not over a thousand feet distant from the southern end of the Wilkeson workings. The veins in the two sets of workings pitch towards each other and undoubtedly form a basin somewhere between the two places. It is the intention of the Carbon Hill Company to ascertain definitely the conditions in this part of their property.

All the veins at Carbonado are involved in a number of small northward pitching folds. They have a steep western dip but a much more gentle eastern one. On the west side of the river the Wingate and Miller veins dip westward at an angle varying from forty to sixty degrees, while in the eastern vein the dip is not more than twenty-five or thirty degrees.

The outside equipment of the mine is very complete. Eight steam locomotives are used in and about the mine for hauling the coal to the bunkers and bringing mining timber from the woods to the mine. About twenty or thirty horses and mules are employed in the mine and outside. A washing plant of 1,200 tons per day capacity is located a mile below the principal mine openings, and at the end of the standard gauge road. It contains three Robinson washers, each having a daily capacity of 400 tons. Power to run the washers is furnished by a little mountain stream which comes down the side of the canyon. The water after generating power to run the machinery is used in washing the coal.

The Carbonado mines have been very active producers for many years, and from them over 4,000,000 of tons of coal have been obtained. The output of the mines in 1902 was 169,733 tons.

Melmont Mine.—The Melmont mine was opened by the Northwestern Improvement Company about one year ago. It is situated on the eastern side of Carbon river canyon, about half way between Carbonado and Fairfax. A rock tunnel 1,500 feet long runs eastward directly across the coal measures and crosscuts seven veins, all of which have been

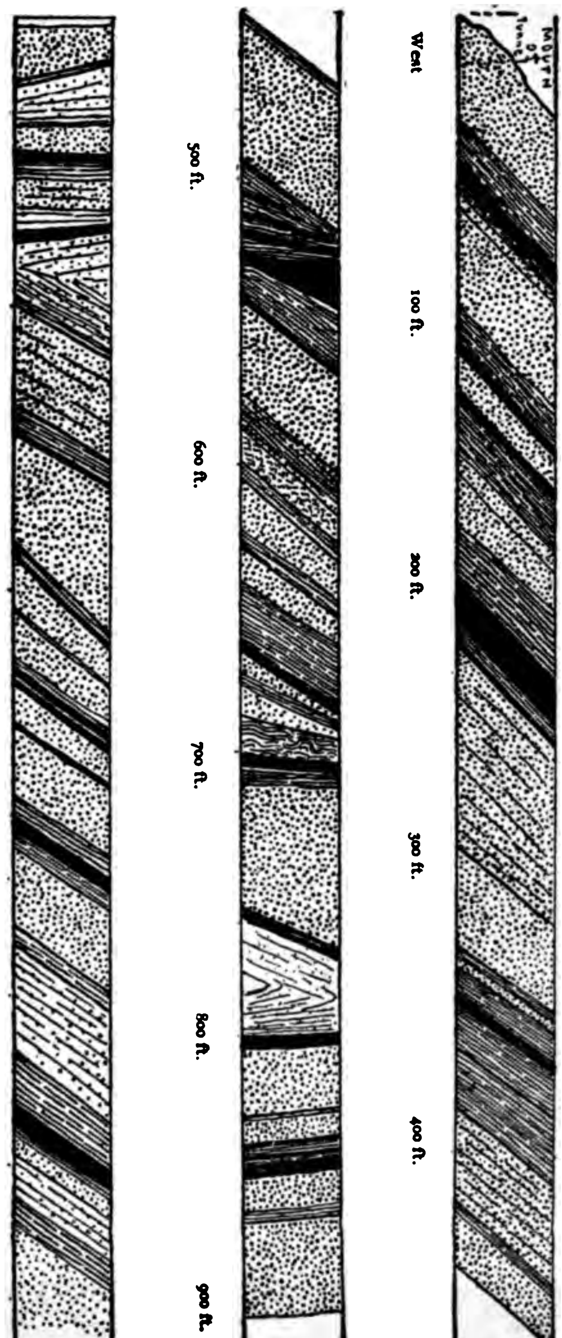


Fig. 25. Cross-section of coal measures, as shown in the Melmont tunnel.

opened by gangways driven northward from the main tunnel. The rock passed through in the tunnel is mostly massive sandstone interstratified with beds of carbonaceous shale. The strike of the measures is about North 10 degrees West and the dip of the veins varies from forty to ninety degrees, the general dip being about sixty degrees. At a distance of 800 feet from the mouth of the tunnel the arch of an anticline was encountered and beyond it for 200 feet the rocks dip to the eastward, or stand perpendicular. At this point the rocks were found to be considerably disturbed and dipping to the westward again, showing that a syncline was passed through. Several more veins besides those encountered in the tunnel are known to occur farther to the eastward, and will be cross-cut when the tunnel is entered.

Vein No. 1 carries about six feet of soft coking coal. It has been opened by a gangway driven several hundred feet northward from the main tunnel. It will not be worked until the company gets its coke ovens ready. Vein No. 2 is also a coking coal. It averages 14 feet in width and has been opened by a gangway 350 feet long. The gangway on No. 3 has been driven north over 1,400 feet. This coal will not coke but makes a first class steam coal and is being used under the company's own boilers. The vein varies in width from thirty feet down to a thin stringer. A layer of coal along the foot wall appears as though it had been partially converted into coke. It has something of the spongy grayish appearance characteristic of coke, and is said to approach it in composition. At the face of the gangway a horse of light gray shale, evidently forced up from below, cuts into the lower part of the vein.

A vein not numbered occurs between No. 4 and No. 5. It contains about three and a half feet of soft coking coal. Vein No. 5 is also a coking coal. A test lot was sent to the Fairfax ovens and it made a first class quality of coke. This vein averages about eight feet in width. A gangway is being driven in it northward from the main tunnel. No. 6 is the last vein encountered in the tunnel. Along it a gangway

has been driven in 800 feet. The width of the coal is irregular, varying from twenty feet down to almost nothing, but averaging about eleven feet of good coal. The relation of the Melmont veins to those of Carbonado and Fairfax is not definitely known but it is evident that if not identical they occur at least in the same general horizon.

At the Melmont mine a large washing plant has just been completed. It is located on a gravel terrace between the mine mouth and the river. It has a daily capacity of four or five hundred tons. The coal as it comes from the mine is dumped onto screens, which separate it into three or four different sizes. The coarse coal falls onto traveling picking tables and the bone and shale are picked out by hand as they pass along. The washing machines, known as the Luhrig washers, are the only ones of the kind used in the state. They are arranged in two batteries, one of four compartments and the other of eight, each compartment being four feet square. A screen is set in each compartment and covered with a three or four inch layer of angular feldspar. The pieces vary in size from a half inch to an inch and a half in diameter. A plunger operated by an eccentric attached to a shaft above forces a body of water up through the screen and rock layers. The force of the water is so adjusted that the coal is carried up through the feldspar but the heavier dirt and rock settles to the bottom and is drawn off at intervals from below. The different sizes of coal are washed in separate machines. From the washers the coal is taken by conveyors to the bunkers, situated above the railroad track, from whence it is loaded on the cars. Only steam coal is being mined at the present time.

Besides the various mine buildings and shops the company has a sawmill turning out 20,000 feet of lumber per day. A large hotel and boarding house furnish accomodations for the company's employes.

Western American Mines.—The mines of the Western American Company were the first to be opened in the vicinity of Fairfax. They began to ship coal about three years ago

and have been steady producers ever since. The company owns about 1,300 acres of land lying on both sides of Carbon river and including the town of Fairfax. The principal mine opening is on the north side of the river, in section 26, where a rock tunnel has been driven across the strata to crosscut the veins. At the point where the veins were encountered the rocks have been involved in several small sharp folds which have destroyed to some extent the regularity of the veins and have interfered seriously with the process of mining. The folds pitch downward at a considerable angle and the gangways driven along the veins have in two or three instances made a sharp backward turn. A number of small faults and slips have been encountered in the workings. The coal shows the effect of these displacements and it has the scaly, distorted appearance which characterizes most of the coking coals of the state, the distortions being much more noticeable in the face of the vein than in a hand specimen of the coal. The company is at present working five veins varying in thickness from two and a half to nine feet. Two veins have recently been opened by a tunnel on the south side of the river in section 34. These veins are probably the same as those being worked at the Montezuma mine a mile further south. The Montezuma gangways have been driven northward to the property line of the Western American Company, and the continuation of the veins on the same strike would carry them to the point where the Western American tunnel has been driven, unless faults should exist in the intervening space.

The structure of the field seems to be that of a main anticline with one or two small secondary folds near its crest. The folds trend about north ten degrees west and the main anticline is apparently the southern continuation of the Wilkeson arch. All the veins pitch downward at angles varying from sixty to seventy degrees. Where the gangways turn back upon themselves when passing around the crest of a pitching fold the veins frequently stand perpendicular.

One of the veins is a good blacksmith coal and about 500

Fig. 26. Cross-section of portion of Fairfax Field.

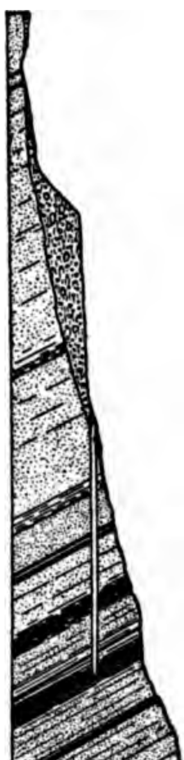


Fig. 27. Cross-section of coal measures, Hillsboro Mine.

tons a month is sold for that purpose. An additional 500 tons is sold for steam coal, and about 2,000 tons is made into coke, making the average monthly output of coal for all purposes about 4,000 tons. The blacksmith coal is nearly all sent to the San Francisco market, and the steam coal is supplied to the Tacoma Eastern Railway for locomotive use.

The washing plant has a daily capacity of about 500 tons, a Howe-Jeffry washer being used. In this machine a powerful column of water forced up from below through the dirty coal carries up with it the pure coal and flows over the top, carrying the coal along with it. A set of revolving arms keeps the whole mass thoroughly stirred up and allows the coal and dirt to separate according to their different specific gravities. The rock particles being so much heavier than the coal gradually settle to the bottom and are drawn off through a spout at the bottom. These machines are probably the most satisfactory now in use, and are more generally used in this state than any other. A fifty H. P. motor is used to run the washing plant.

Power to run all the machinery of the mine is taken from the water of Carbon river. A flume three-fourths of a mile long brings the water to the power plant situated a short distance from the mine mouth. The total capacity of the plant is 600 H. P., but at the present time only 500 H. P. is being generated. The power is used to run the washer, the ventilating fans, electric locomotives, machine shop, blacksmith shop, and electric light machines. In addition to these, power is furnished during the dry summer months to the Montezuma mine to run their washing plant. A small flume leading off from the main flume supplies water to the washer. The electric light plant supplies the mine, the washer, and the town of Fairfax.

The Western American Company has sixty coke ovens in operation. The coal is sent from the washers to the ovens by means of a flume. At the lower end of the flume a conveyor hoists the coal from the flume to the hopper from which it is drawn into a dump car. The car runs on a track

between the two lines of ovens and dumps the coal into the ovens from above. The charge for each kiln varies from four to six tons of coal.

Two qualities of coke are produced, one for smelter use and the other for foundry use. The smelter coke is burned for forty-eight hours and the foundry coke for seventy-two hours. The seventy-two hour coke is firmer and stronger and of a better quality than the other. Most of the coal used for making coke comes from two veins opened on the north side of the river. This coke commands a ready sale and the company finds it impossible to fill all of the orders which come to it.

The output of the Western American mine in 1901 was 30,513 tons of coal, and in 1902, 32,117 tons.

Montezuma Mine.—This is the joint property of the Washington Co-Operative Mining Company and the Montezuma Mining Company. There is a mutual working agreement between the two companies by which the mine is operated under one management. Their property extends along Evans creek southward from its mouth for four miles, and embraces a total area of 2,120 acres of coal bearing land. The mine has been in operation for less than a year, the first coal being shipped in the spring of 1902. The daily output is still small and no attempt will be made to increase it until the coke ovens are ready for use. Twenty-five ovens are now being built, and will probably be finished by the beginning of 1903.

The principal openings of the Montezuma mine are located on Evans creek, about a mile above its mouth. Evans creek is a swift mountain stream entering Carbon river from the south about half a mile above the town of Fairfax. It drains part of the region between the headwaters of Carbon and Puyallup rivers, and flows for a considerable part of its length over coal measures. For the greater part of the year it carries a large volume of water but during the dry summer months it dwindles to a comparatively small stream. Where the Montezuma tunnels have been driven the veins cut diag-

onally across the creek, the general strike of the measures being North twelve degrees West. On the east side of the creek a water level tunnel was driven through the sandstone and shale for a distance of 350 feet, in order to reach a vein known as the east vein. After reaching the vein a gangway was driven on it some distance, and it was found to vary in thickness from two and a half to four feet. On the opposite side of the creek another tunnel 528 feet long crosscuts two veins, known respectively as the blacksmith vein and the

Fig. 28. Fault in the Montezuma Mine.

steam vein. The point where these veins were opened is not very far from the north line of the company's property, so that the gangway driven northward from the main tunnel on the blacksmith vein reached the boundary line at a distance of 580 feet and was stopped. The Western American Company owns the extension of these veins. Both veins are being worked only to a limited extent at the present time. There is a larger demand for the blacksmith coal than for the steam coal, and as it commands a much better price it is being worked more extensively than the steam vein. The coal

from both veins is extremely soft, and a large part of it reaches the market in the form of fine slack. The south gangway on the blacksmith vein is about 1,050 feet in length (October, 1902). Near the main tunnel it encountered a small fault which displaced the vein fifteen feet. At a distance of seven hundred feet it ran into a much larger fault and the vein was lost completely for a distance of two hundred feet, when it was again picked up. When measured at the face of the gangway October 13th, 1902, the vein was sixteen feet wide, all clean coal except a band of dirt a foot or two wide near the middle of the seam. In the north gangway on the same vein about five feet of coal appears.

The steam vein was encountered 525 feet from the mouth of the tunnel. Gangways have been driven north 200 feet and south 550 feet. On the north face of the gangway the vein has a total width of eight feet ten inches, only five and a half feet of which is good coal. On the south end the total width is six feet ten inches, with a seam of coal four feet ten inches thick on the foot wall. The coal in this vein is overlaid by a band of shale from two to three feet thick.

Another vein eleven feet wide shows in the creek bottom just below the sawmill and has been prospected by a tunnel two hundred feet long. It is rather dirty and work on it has been abandoned. Two other veins appear in the creek between the eleven foot vein and the east vein, but have not yet been opened. A half dozen or more other veins are known to occur on the property, but beyond occasional outcrops nothing is known of them.

All the veins encountered in the tunnels dip to the westward at an angle of about seventy degrees. The line of strike would carry them to a point a mile north where the Western American Company have opened a tunnel on the south side of the railway track and where they crosscut two veins. Two or three hundred yards east of this place an anticline shows along the railway track. It is quite probable that this anticline extends southward and passes only a short distance to the eastward of the present Montezuma workings.

The outside equipment of the Montezuma mine consists

of a washing plant, sawmill, machine shop, blacksmith shop, and water-power plant, besides numerous small buildings. The power plant gets its water from Evans creek through a flume 800 feet long. The penstock is ninety feet high and is connected with a 350 H. P. Victor turbine. Additional power is also furnished by a small 15 H. P. Pelton wheel connected with the penstock by an eight-inch pipe. It is used only in dry weather when there is not enough water in the creek to run the big wheel.

The washing plant is capable of handling a considerably larger output than is being produced at present. The coal as it comes from the mine is first screened and the coarse coal hand picked. The fine coal is sent to the Forrester washing machines. These work in sets of two each, one machine being set a foot or two higher than the other in order that the coal after being washed in the first may pass to the second to complete the washing.

A double flume nearly a mile long runs from the mine to the lower camp, one side of it being used for coal and the other for lumber. The bunkers have a capacity of 800 tons. There are two compartments, one being used for blacksmith coal and the other for steam coal. The flume which carries the coal leads directly to the bunkers, so that they act as settling tanks and are built practically water tight. The sawmill has a daily capacity of ten to fifteen thousand feet and supplies all the lumber and shingles used by the company.

The town of Montezuma, which includes the company's store, boarding house, and cottages for the employes, is situated on a gravel terrace at an elevation of 100 feet or more above the river bottom and about half a mile below the mine. Twenty-five coke ovens are being erected on the river bottom near the point where Evans creek enters Carbon river. When completed the ovens will have a capacity of sixty-five tons of coke per day. All the coal from the steam vein and the fine slack from the blacksmith vein will be coked.

Hillsboro Mine.—The Hillsboro Coal Company is an allied organization of the Olympic Mining Company of Seattle.

Its property consists of 1280 acres of coal land, including section 36, T. 18 N., R. 6 E., and section 6, T. 17 N., R. 7 E., lying on both sides of Carbon river a mile or two above the town of Fairfax. The mine opening is in section 36, on the north side of the river. A rock tunnel was begun in January, 1902, and was driven eastward to crosscut the veins which were known to outcrop on the side of the mountain above the camp. The tunnel is now in a distance of 725 feet and there are six veins exposed, varying in width from one foot to eight feet. The last vein, known as No. 6, is eight feet wide and shows good coal nearly all of the way across its face. A chute has been begun on this vein and will be extended upward to the surface. An analysis of the coal in No. 6 made by Mr. Paul Hopkins gave the following percentages: Water, 1.00; volatile matter, 11.98; fixed carbon, 79.01; sulphur, .54; ash, 7.47.

This coal gave the highest percentage of fixed carbon and the lowest percentage of volatile matter of any from the vicinity of Fairfax, and shows that it possesses high heating power. The moisture and sulphur are quite low. Its coking qualities have not yet been tested, but from its similarity to the known coking coals of the district it is assumed that the Hillsboro coal will make good coke. A small amount of development work has been done on veins No. 2, No. 3 and No. 4 where they were crosscut in the tunnel. A further extension of the mine tunnel will encounter several more veins lying higher in the series whose outcrops have been found. The mountains to the north of the main tunnel rise steeply and the northern gangways will gain considerable depth on the veins.

A number of veins outcrop on the company's property on the south side of the river. Several of them have been uncovered, but not much work has been done upon them. All of th veins on the Hillsboro property lie to the eastward of those worked at Fairfax and Montezuma and probably occur higher in the series. The coal measures all dip at a steep angle and the numerous outcrops on the two sections, 6 and 36, probably represent a thickness of three or four thousand feet of strata.

The enclosing rocks are massive, light colored sandstone

and very dark carbonaceous shale. The veins all pitch eastward at a very steep angle and show the effects of great crushing. It is probable that the coal measures extend only a short distance eastward beyond the boundaries of the company's property. A short distance above, on Carbon river, the sedimentary strata are replaced by igneous rocks derived in large part from Mount Rainier, whose summit lies to the southeast about twenty miles away.

As soon as the mine can be put in shape for producing coal on a considerable scale the railway will be extended from Fairfax to the mines, and bunkers will be built. The railroad will pass along the south side of Carbon river past the Montezuma bunkers and cross the river about three-fourths of a mile below the Hillsboro camp. It is also the intention of the company to build coke ovens and go into the manufacture of coke. All the coal will be made into coke unless some of it should prove to be more valuable for blacksmithing purposes.

The company operates a sawmill having a daily capacity of 15,000 feet, in order to supply lumber for its own use. A small air compressor is also in use, furnishing power to run the Rand drills used in the rock tunnel. The camp, consisting of the company store, boarding house. blacksmith shop, offices and dwelling houses, is located near the mine mouth. A good wagon road extends from Fairfax to the mine.

KITTITAS COUNTY.

Roslyn-Clealum Field.

This coal field is on the main line of the Northern Pacific Railway, about fifteen miles east of the main divide of the Cascade mountains. It occupies the valley of the Yakima river near the point where the Yakima is joined by the Clealum. The coal seams occur in a massive, light colored sandstone of Eocene age, to which the name Roslyn sandstone has been applied. The Roslyn formation is a lake deposit of limited area and has a total thickness of not far from 3500 feet. The Roslyn coal basin is the most extensive and valuable in the state and at present has an output equal to all the others

combined. The two most important veins in the series are the Roslyn and Clealum veins, working respectively at Roslyn and Clealum. These two mines are three and a half miles apart and their underground working are not connected. It is still an open question whether or not the two veins are identical, and this problem has a most important bearing on the future of the field. It is generally believed, however, that the Clealum vein is a different one from the Roslyn and lies several hundred feet higher in the series. The strata dip to the southwest at an angle varying from ten to fifteen degrees. The outcrop of the Roslyn vein makes an exceedingly tortuous line along the mountain side northeast of the two towns of Roslyn and Clealum. Its general direction, however, is southeast and northwest. The rocks have not been greatly folded or faulted and the coal has been but little disturbed. It is a bituminous coking and steam coal. It is quite hard and compact and nearly all of it reaches the market as lump coal. It is used very largely as a steam coal for locomotives and steamships and supplies very much of the market of Eastern Washington, Idaho and Oregon for steam and domestic coal. Large quantities are shipped to Puget Sound, Portland, San Francisco, and even Honolulu. The Northern Pacific Railway uses it exclusively in its locomotives as far east as Helena, Montana. The Great Northern Railway heretofore has had a large standing order for Roslyn coal, but within the past few months it has completed a line of its own to the Crow's Nest coal field of British Columbia and is now using that coal chiefly on all its lines in Washington, Idaho and Montana.

The Roslyn and Clealum mines are operated under one management by the Northwestern Improvement Company. The company owns practically the entire coal basin. Several small, independent companies control small tracts within the coal area, but as a rule they are not able to compete with the big mines. One of them, the Ellensburg Coal Company, has a small mine two miles north of Clealum on a forty-acre tract. The vein upon which they are working is the same one as that being worked at Clealum. The coal is hauled in wagons to Clealum and sold about town for local use.

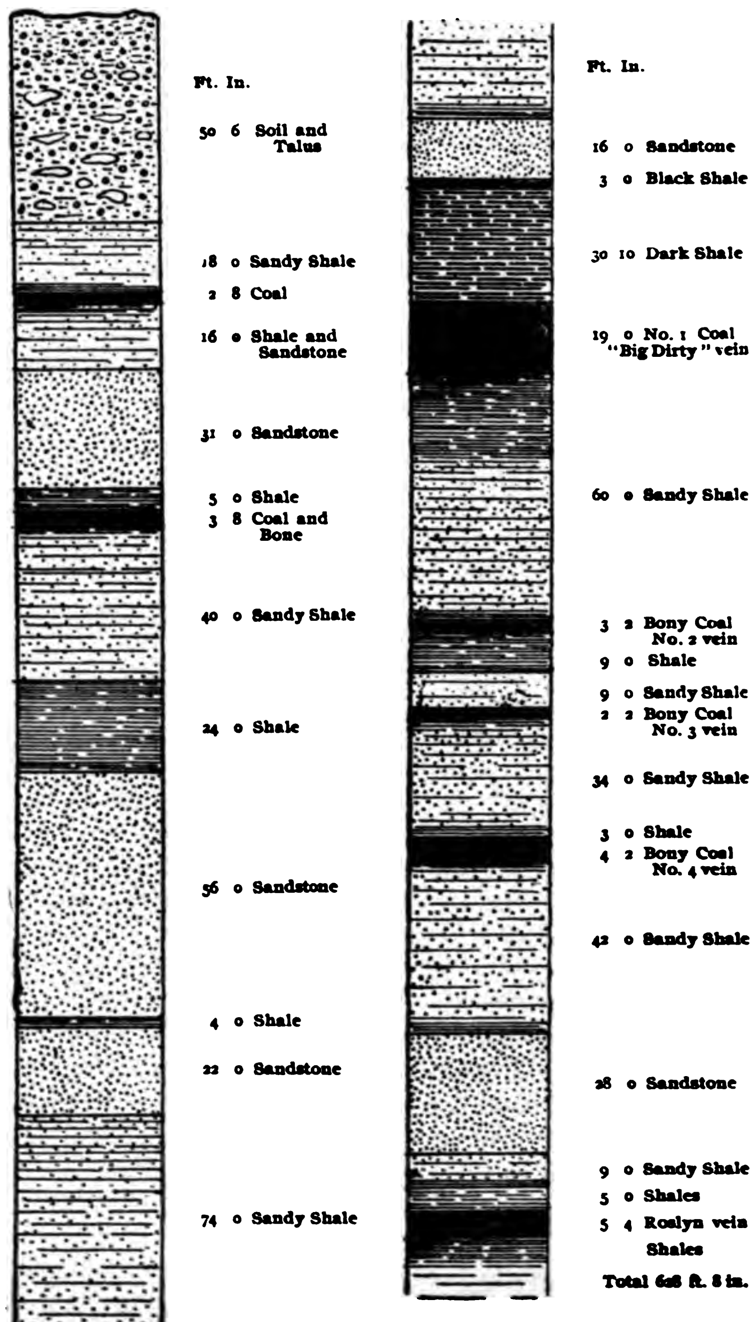


Fig. 29. Cross-section of Coal Measures as shown in Roslyn Shaft.

Roslyn Mine.—This mine is at the head of a branch road three and a half miles long which runs to Clealum on the main line of the Northern Pacific Railway.

The Roslyn mine is opened on the northern rim of the coal basin at a point where the vein outcrops along the sides of a small gulch. Tunnels have been driven east and west on the vein from this point. The underground workings include a considerable part of five sections of land, and are being rapidly extended. Besides the tunnel entrances to the mine there is a shaft 625 feet deep which taps the vein about half a mile south of the tunnels. The Roslyn vein, which is the only one

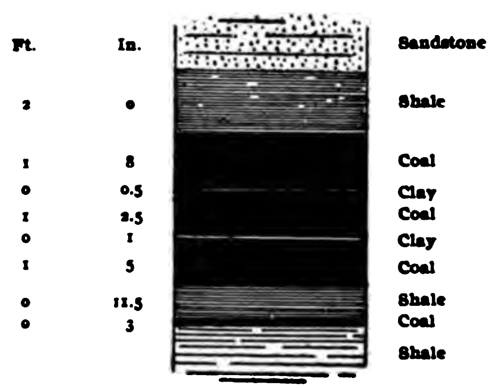


Fig. 30. Cross-section of Roslyn vein, Roslyn Mine.

worked in the mine, averages about four and a half feet in width and dips southeast at an angle varying from ten to twenty-five degrees. In nearly all parts of the mine the cars can be run up the breasts and loaded directly at the face of the workings. The tail-rope system of haulage is very largely employed in this mine. A system of wire cables stretches along the various gangways of the mine and are all connected with the engines on the outside. Some of the cables haul the cars from the inner workings to the gathering points, where they are made up into larger trips and hauled to the outside by another cable. Several small electric locomotives are also employed on the inside to gather the trips together. The

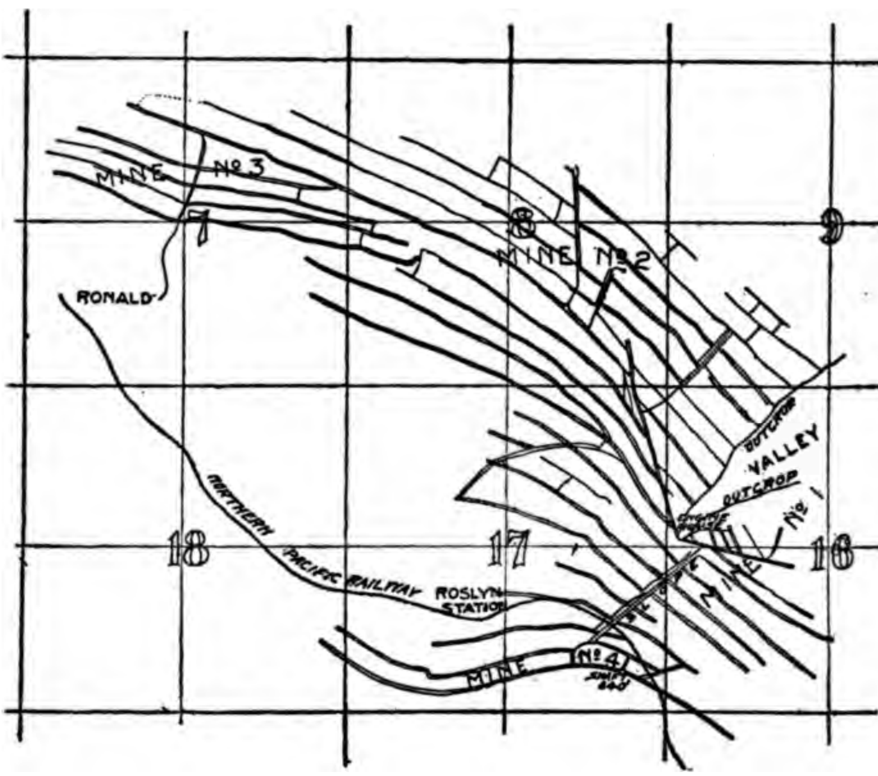


Fig. 31. Map showing the extent of the underground workings in the Roslyn Mine.

shaft is divided into two compartments, in each one of which is a double-deck hoist. The hoists work alternately with each other and each trip carries up two cars, or about 5000 pounds of coal. The daily output by way of the shaft is about 1800 or 2000 tons, and the total output of the mine at the present is not far from 3000 tons per day. The coal is not washed, but is shipped just as it comes from the mine. The vein is practically all clean coal, there being only two thin clay partings. The mines are well ventilated and very little trouble is experienced from gas.

The Roslyn mine was opened in 1885, and in all has produced over 7,000,000 tons of coal, taken from an area of about 1200 acres. The total output for 1901 was 1,005,027 tons, and for 1902, 1,039,870 tons.

Fig. 32. Cross-section of vein, Ellensburg Coal Co's Mine.

Clealum Mine.—The town of Clealum is on the mine line of the Northern Pacific Railway and has an elevation of 1900 feet above sea level. A branch line three and a half miles long runs to Roslyn, which is about 300 feet higher than Clealum. On the north side of the valley a ridge of sandstone parallels the river and rises about 1900 feet above the stream. On the south side of the valley a ridge of basalt rises 2500 feet above the valley floor. Several clearly marked gravel terraces occur on each side of the river, rising by steps to the base of the mountains. These heavy gravel deposits cover the coal

bearing rocks and serve to obscure the outlines of the coal basin.

The Clealum mine is opened by a shaft and a tunnel at the base of the mountain on the northern outskirts of the town. The shaft is 250 feet deep. The vein is four feet six inches wide and is practically all clean coal. The dip of the vein varies from twelve to twenty-three degrees to the southward. From the bottom of the slope four levels have been run, the longest of which is about 5000 feet. Only one fault has been encountered in the mine, a small overthrust between the first and second levels. The daily production at present is seven or eight hundred tons, and the mine is rapidly being put in shape for a more extensive output. The mine was opened in 1894. In 1902 the amount of coal mined was 212,584 tons.

THURSTON COUNTY.

Bucoda-Tenino Field.

The Bucoda-Tenino district lies in the southern portion of Thurston county. Its boundaries are not definitely fixed in any direction. A large part of its surface area is composed of flat river bottom and barren gravel plains, and it is only where the coal-bearing formation appears at the surface along the hillsides and on higher ground that it is possible to discover any outcroppings of coal.

Coal was first discovered in the valley of the Skookumchuck in 1855. It was mined in the vicinity of Bucoda in early territorial days, the convicts of the penitentiary being employed for that purpose. The early mines are now closed down and it is difficult to get definite information regarding them.

The Chehalis and Skookumchuck rivers flow through wide, level valleys. Hills of sedimentary rocks belonging to the coal-bearing series border the valleys and rise to heights of several hundred feet. During late glacial time the melting of the great ice mass which occupied the basin of Puget Sound caused a tremendous flood of water to sweep southward over this region. This great river was heavily loaded with sedi-

ments of all degrees of coarseness, which it dropped by the wayside as it passed along. In the northern part of the field in the vicinity of Tenino the gravel is quit coarse, and water-worn boulders are scattered everywhere. Traveling southward into Lewis county the material gets finer and finer until in the vicinity of Chehalis it is a fine, sandy loam with no gravel. South of Chehalis there are no signs of glacial action whatever.

The Seatco coal mine was opened in 1880 near the town of Seatco, the name of which was afterwards changed to Bucoda. It was operated with convict labor taken from the territorial penitentiary, which was at that time located at Seatco. Public sentiment was hostile to the enterprise, however, so that the convict system was soon discontinued and the mine closed down. Operations were conducted on an eight-foot vein of coal and altogether about 10,000 tons of coal were mined.

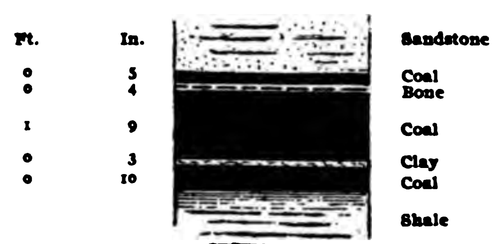


Fig. 33. Cross-section of vein, Great Western Mine, Tenino.

The Great Western Coal Company owns about 2100 acres of coal land two or three miles southwest of Tenino and has opened a small mine on its property. It has driven a tunnel for a distance of seven hundred feet on one of its veins where it outcrops at the base of a small hill. The vein lies nearly flat, with only very slight undulations, and is not more than three or four feet thick. There are only about half a dozen men employed in the mine and two or three cars of coal per week are being shipped. The coal is a typical brown lignite and carries a high percentage of moisture.

LEWIS COUNTY.

Lewis County contains coal at intervals throughout its whole length from east to west. The county is about ninety-six miles long and twenty-five miles wide, and stretches from the main divide of the Cascade mountains westward to the foot-hills of the low mountain range which borders the coast between Gray's Harbor and the Columbia river. The western part of the county forms part of the wide, level valley or plain which stretches from Puget Sound to the Columbia and which is continued southward into Oregon as the Willamette valley. From Chehalis eastward the land rises gradually into the Cascade range. It is along the principal river, the Cowlitz, and its tributary, the Tilton, that most of the coal prospects have been found. In the low, level country in the western part of the county nearly all of the rocks belong to the coal measures, and have in most places been folded only to a slight extent. Igneous intrusions are occasionally found traversing these rocks. To the eastward, as the mountains are approached, the country becomes more broken and the eruptive rocks form a more and more prominent feature until in the eastern end of the county they constitute practically the whole mass of the mountains, with only occasional small outcrops of sedimentary rock.

The coal of Lewis County offers a good example of the alterations brought about by folding and the intrusions of igneous rocks into the coal measures. From the low,level country in the western part of the county to the mountainous country to the eastward the coal shows a gradual transition from lignite to semi-anthracite. The brown lignite of Chehalis and Centralia and the semi-anthracite of Verndale occupy extreme positions on the scale. They are both of the same age and probably have both had approximately the same load of overlying sediment. The main difference has been that in the Verndale region the coal has been folded, broken across and overflowed by great bodies of eruptive rocks, while at Chehalis and Centralia the rocks have been tilted only to a slight degree from their original horizontal position, without under-

going any great degree of crushing or folding and without much loss of their volatile constituents. Many intermediate types of coal are represented in the valleys of the Cowlitz and Tilton rivers at Alpha, Cinebar, Morton, and Sulphur Springs.

The lignite field of Lewis county may be said to extend from the western end of the county as far east as Alpha, where a number of veins of this character have been prospected. Bituminous coal occurs at Cinebar, about ten miles east of Alpha, in a region where the strata have been broken by dikes and considerably crushed and folded. Still further eastward, in the Morton and Verndale regions, the surface rock is nearly all of igneous origin and the coal has been reduced to anthracite or semi-anthracite. The coal of the Packwood and Davis prospects in the Cowlitz pass region is of this same type.

Chehalis-Centralia Field.

Lignite of a rather inferior quality occurs in the region about Chehalis and Centralia, and has been mined on a small scale for the local trade for several years. It is sold in these two towns chiefly as a domestic coal, but is used to a limited extent for making steam. It is so situated as to be mined very cheaply and its low price enables it to compete in the local market with outside coals of much superior quality.

The general aspect of the region is that of a level plain with low rounded hills rising at intervals above the surrounding country. The coal measures appear along the hillsides and coal outcrops are known to occur at many places. A number of attempts have been made in the past to open up some of the numerous coal veins and place the product on the market, but at the present time there are only two mines in active operation, and neither of these produce more than a few tons per day.

Rosenthal Mine.—A small mine is being worked in section 29, just outside of Chehalis, on the Rosenthal property. Four veins show along the hillside, varying in thickness from two and a half to twelve feet. The only vein being worked at present is about four feet thick. A tunnel has been driven into the

base of the hill for a distance of 250 feet and the coal above it is being worked out. Only two or three men are regularly employed in the mine and all the coal is sold in Chehalis. Some of the other veins on the same property have been

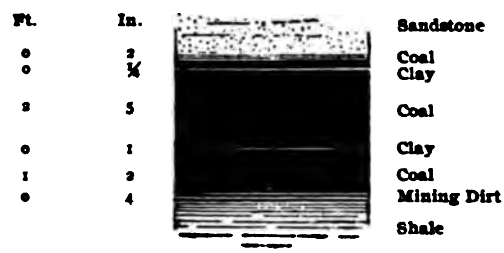


Fig. 34. Cross-section of vein, Rosenthal Mine, Chehalis.

worked in the past. All of the coal carries high percentages of ash and moisture and a correspondingly low percentage of fixed carbon.

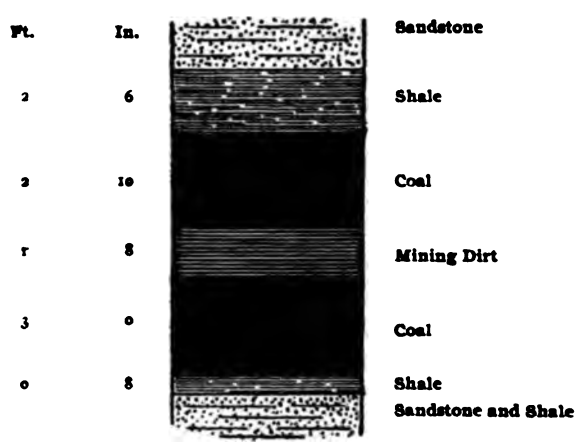


Fig. 35. Cross-section of vein, Salzer Valley Mine, Secs. 22 and 23, T. 14 N. R. 2 W.

Salzer Valley Mine.—The town of Centralia is supplied by the Salzer valley coal mine, situated about four miles east of the town in sections 22 and 23. There is only about forty-five acres in the property and the output is very limited. Three

veins are known to occur, all lying nearly flat, and dipping only about four degrees. The lowest vein, which is the only one being worked at present, is about seven feet wide and contains two benches of coal two feet and three feet wide respectively, and separated from each other by about twenty inches of clay. Another vein ten feet wide lies 200 feet above the first one. A tunnel 400 feet long was driven on this vein and about 1500 tons of coal taken out, but nothing has been done on it for the past three years. A third vein occurs about fifty feet higher in the series, but has never been prospected.

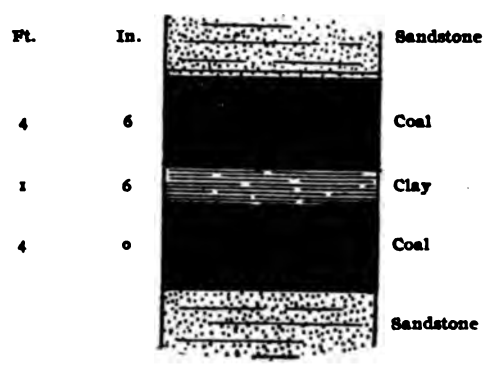


Fig. 36. Cross-section of No. 8 vein, Crescent Mine, Claquato.

Claquato Mine.—A new prospect has lately been opened up near Claquato by the Crescent Coal Company. Three veins have been found, ranging in width from five to eleven feet. A tunnel is being driven on the middle one, which contains two benches of coal, each about four feet wide, with a layer of clay eighteen inches wide in the middle. The veins dip to the southward at angles varying from twenty to forty-five degrees.

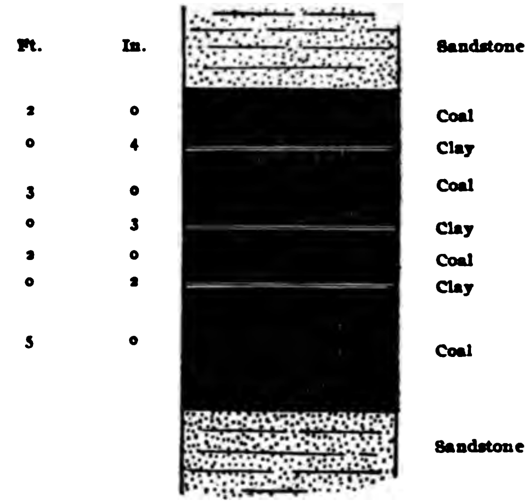


Fig. 37. Cross-section of No. 10 vein, Crescent Mine, Claquato.

Alpha Field.

A lignite field of limited extent occurs near Alpha post office about eighteen miles east of Chehalis, in townships 13 and 14 N., R. 1 E. The region is one of low relief and there are very few exposures of rock in place, consequently it is impossible to define the actual limits of the area that is underlaid with coal. Some prospecting has been done in sections

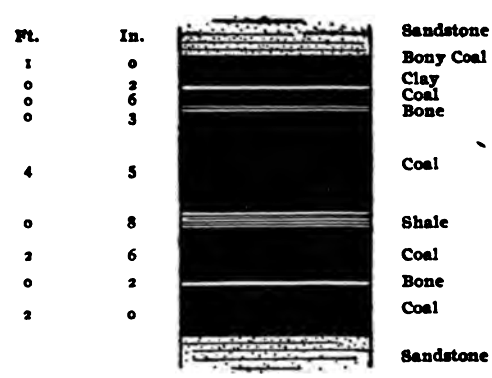


Fig. 38 Cross-section of vein, Hannaford Creek, S. W. ¼ sec. 32 T. 15 N. R. 1 E.

2, 4, 8, 9, 10, and 11, T. 13 N., R. 1 E., and in sections 32 and 34, T. 14 N., R. 1 E. It is said that the coal was not found of sufficient value to encourage further work and it was therefore suspended. Four tunnels varying in length from thirty-five to ninety feet were driven, besides a number of open cuts and test pits. Several veins were exposed, varying in width from five to ten feet, and dipping to the southwest at an angle of about 45 degrees. They were traced for about two and a half miles. The coal is said to be traversed in places by dikes, which have caused a local change from lignite to bituminous coal. No work is being done at present in this field.

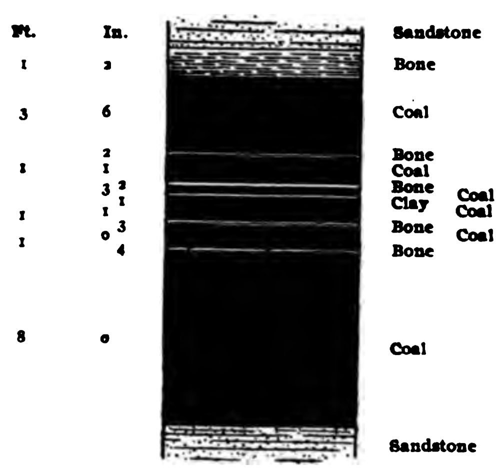


Fig. 39. Section of vein, Hannaford Creek, N. W. ¼ sec. 32 T. 15 N. R. 1 E. (W. J. Wood.)

Cinebar Field.

Cinebar Mines.—The Cinebar coal mines, owned by the Columbia Coal and Coke Company, are opened on a little stream known as Sherman creek, which flows into Tilton river about a mile south of Cinebar post-office. The coal-bearing rocks lie along the southern base of a range of hills which parallels Tilton river for twelve or fifteen miles. In this part of its course Tilton river flows in a deep, narrow gorge, above which is a comparatively level valley, largely under cultivation. The mines are opened along the northern edge of the

valley just where the hill begins to rise. The hills are covered with thick timber and the soil is quite deep, so that surface prospecting cannot be carried on except in some of the stream beds, and consequently the extent of the coal-bearing rocks is not definitely known. Coal croppings have been found on Bear creek, which parallels Sherman creek, about a mile to the eastward, and on Cinebar creek about the same distance to the westward. The coal veins on Cinebar creek and its tributary, Coal creek, has been quite extensively prospected and are supposed to be identical with those now being opened up on Sherman creek.

There are about a dozen veins outcropping on Sherman creek, and all of them have been prospected more or less by a number of short tunnels which have been driven on the different veins, the longest being 256 feet on vein No. 5. A crosscut tunnel 1900 feet long runs at right angles to the strata and brings to view a number of veins, on some of which gangways have been driven. Vein No. 5 is about nine feet thick and shows at its mouth clean, hard coal, but further along in the tunnel the coal becomes dirty in places and near the end of the tunnel is involved in a small fault. The coal in all the tunnels makes a little gas, so that safety lamps have to be used to some extent.

All of the veins thus far developed show signs of crushing and sliding whereby the wall rock has become mixed with the coal to such an extent as to render a large amount of it too dirty to be of any commercial value. This loss in part is the price which it seems must be paid for bituminous coal in rocks so recent as the Eocene. The forces which changed it from lignite to bituminous have caused a more or less serious loss in the quantity of clean coal. Where the dirt partings in the veins are clearly defined the task of separating the dirt from the coal is comparatively easy, but in such veins as those of Cinebar, where the whole contents of the vein and part of the wall have ben formed into an intimate mixture, it is a difficult undertaking to separate them. The process of rolling to which the veins have been subjected has reduced most of the coal to a powder, so that it crumbles at the touch,

and a very large percentage of it will reach the market in the form of slack. This difficulty may be obviated by making it into coke at the mine, and probably the most of it will be treated in this way.

It is planned to build a railroad into the Cinebar field by way of the Cowlitz valley so as to give as short and easy a route as possible to the Columbia river. The nearest railroad point at present is Chehalis, twenty-five miles away. On account of the abundance of good coal tributary to Puget Sound cities, and its almost entire absence in the region immediately tributary to Portland, it is thought advisable to market all of the coal in the latter city and thereabouts.

Morton Field.

The Morton coal prospects lie about fourteen miles east of Cinebar, and forty miles east of Chehalis, the nearest railroad point. A wagon road leads from Chehalis to Morton by way of Alpha and Cinebar, and all the travel to and from the district is over this route.

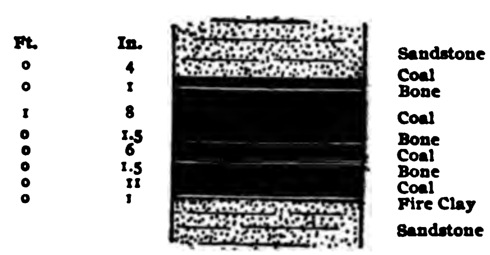


Fig. 40. Cross-section of No. 2 vein, sec. 30, T. 13 N. R. 5 E. (Morton Field.)

The coal outcrops in the Morton field occur in a number of isolated localities separated from each other by bodies of igneous rock, which in this region appear to have overflowed the coal measures. The region is one of high mountains, composed almost entirely of igneous rock, the small areas of coal measures forming comparatively insignificant features of the landscape. Their boundaries have never been traced out, so that the actual extent of country underlaid with coal is quite

unknown. A considerable variation is found in the analyses of the coal from different prospects, the dissimilarity being probably due to the greater intensity of volcanic action in some localities than in others. The coal is quite hard and does not show evidence of having been subjected to much internal movement, its bituminous character being due rather to the close proximity of large passes of igneous rocks. Nearly all the other bituminous coals of the state except those of Roslyn are quite soft and mine very small, but a large percentage of the Morton coal can be placed upon the market as lump and nut coal. The coking qualities of the Morton coal have not yet been tested.

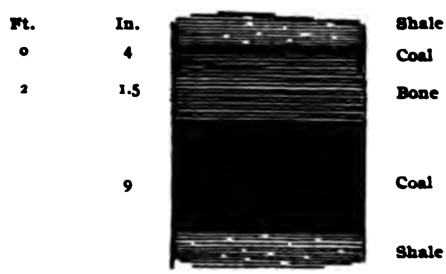


Fig. 41. Cross-section of vein, sec. 6, T. 12 N. R. 5 E. (Morton Field.)

There is one prospect upon which considerable work has been done and which shows better quality of coal than that found elsewhere in this field. This is in section 6, T. 12 N., R. 5 E., near Davis lake, where a slope 350 feet long has been sunk on a vein which outcrops along the hillside northeast of the lake. The vein is from three and a half to four feet wide and is fairly regular all the way down the slope. Short gangways have been driven in both directions from the slope and some of the coal has been taken out for use in the boiler which supplied the hoisting engine at the top of the slope. An analysis of the coal gave the following percentages: Water, 1.57; volatile matter, 7.87; fixed carbon, 84.82; sulphur, 1.70; ash, 4.04. The heating power of this coal is very high and it has been found to work well in the furnace. Its composition

places it in the semi-anthracite class. There are six other veins lying at short intervals from the main vein and a number of short prospect tunnels have been driven upon them.

The prospect described above is the most promising one in the Morton field, owing to the regularity of the veins and the high character of the coal. More development work, however, will have to be done upon it before the mine will be in shape to make extensive shipments, even if transportation facilities were at hand. It is forty miles to the nearest railroad point, and for this reason development work has been necessarily slow. The Cowlitz and Tilton river valleys offer an easy railroad grade all the way to the mines and the construction of a railroad does not present any serious engineering difficulties.

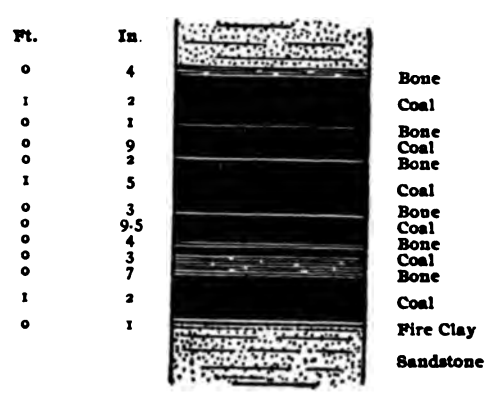


Fig. 42. Cross-section of No. 1 Vein, sec. 30 T. 13 N. R. 5 E. (Morton Field.)

In section 12, T. 12 N., R. 4 E., on the opposite side of Davis lake from section 6, Mr. E. E. Edmond has driven a small tunnel on a coal vein which he says is nine feet thick. Several veins are said to outcrop on the mountain side south of this place.

Three or four miles north of Davis lake, at the forks of Tilton river, there is a coal area covering about six sections of land. Some development work has been done on sections 24 and 30. Six veins are said to occur, varying in width from

three and a half to eight and a half feet. An analysis of the coal from section 24, T. 13 N., R. 4 E., gave the following percentages: Water, 3.71; volatile matter, 35.03; fixed carbon, 59.01; sulphur, 1.24; ash, 1.01. A sample from section 30, which adjoins 24, gave somewhat similar percentages: Water, 1.80; volatile matter, 34.27; fixed carbon, 58.93; sulphur, 1.34; ash, 3.66.

Another prospect is located on Connolly creek in section 26, T. 13 N., R. 4 E. The vein is six feet wide and has been opened by a tunnel sixty feet long, from the end of which a slope was sunk on the vein sixty feet. Nothing is being done on it at the present time.

North of Verndale some work has been done in section 20, T. 13 N., R. 6 E. This location is at the very headwaters of the east fork of Tilton river. The coal outcrops in the bed of the stream at the bottom of a deep gulch. The seams of clean coal are only a few inches thick and the whole formation has been greatly distorted by the intrusion of eruptive rocks, which constitute practically all the surface rocks of the region. An analysis of the coal shows the following percentages: Water, 2.67; volatile matter, 4.86; fixed carbon, 88.66; sulphur, 1.22; ash, 2.59. The coal has a steel-gray appearance and is extremely hard and compact.

PACKWOOD FIELD.

The Packwood coal field is the name locally applied to a region on the headwaters of the Cowlitz river, in the Mt. Rainier Forest Reserve. The coal beds to which the name of Packwood has been definitely applied outcrop on the south side of the Cowlitz, just north of Lake creek, about twelve miles northeast of the post-office of Sulphur Springs.

The valley of the Cowlitz river from Cora post-office, twenty-three miles due south of Mt. Rainier, to the junction of the Clear and Muddy forks, about seventeen miles up-stream to the northeast, has a width varying from one-half to two miles. Spurs of the Tatoosh and Sawtooth ranges form the northwestern walls of the valley. The ridges bordering it on the southeast extend back to the main divide of the Cascade range

and culminate in Goat mountain, at an elevation of 5000 feet. The broad, alluvial floor of the Cowlitz valley has a very even rise from about 800 feet at Cora to 1500 feet at the mouth of the Muddy fork.

The coal-bearing shales and sandstones outcrop along the banks of the main river in a few places, but there are more numerous and clearer exposures in the gorges cut by the streams entering the valley from each side, and on the intervening ridges. The strata lie mostly within a few degrees of the horizontal. They appear to be free from faults and abrupt folds, but observations made at a number of different points in the region show the direction of dip to vary greatly.

The chief prospects in the Packwood field are located three miles southeast of the Cowlitz river and two miles north of Lake creek, at an elevation of 2600 feet. The workings have a total length of 600 feet. Clean coal lies in thin layers interbedded with shale, which in some cases is highly carbonaceous. The thickness of these layers is most commonly from one to three inches, along with a number of vein-like streaks about one-fourth inch thick, and a few layers from eight to ten inches thick. Some are continuous for several hundred feet, but the majority are short and taper very gradually at the ends. The beds are overlaid by an igneous rock, which at other points near by shows evidence of intrusive origin. At several points in the workings the contact of the igneous mass with the coal shales is plainly shown.

All of the coal exposed in the tunnels is slacked and crumbles readily, due to its exposure to the atmosphere for several years. Fresh coal, taken a few feet from the face, ignites with difficulty, burns with a short, blue flame, gives intense heat, and leaves a small amount of gray ash. No pyrites of iron is visible in any of the coal.

Three-eighths of a mile east of the Packwood prospects, just north of the divide between Lake and Coal creeks, two short tunnels have been driven in coal-bearing shales which seem to belong to the same series as those just described and which may be identical with them, although the cannection

cannot be traced accurately. Several feet below the coal a layer of sandy shale contains petrified wood in the form of roots, twigs and stumps. Most of the woody matter has been replaced, but enough carbonaceous material remains to give the specimens a black color, which can be removed by heating.

Pure coal interbedded with carbonaceous shale and sandstone occurs at a number of places in the beds of Coal and Lake creeks, on the high, steep ridge between them, and along the smaller creeks to the north and south. The hard, firm texture of the coal accounts for the amount of it found as float in all the creeks of the region.

Davis Field.

The first main trail crossing the Cascades south of Mt. Rainier is known as the Cowlitz, starting from Sulphur Springs on the western side of the range, and ending in the Titon basin. The trail follows the Cowlitz river up to its main fork, thereafter following the east or Clear fork for several miles, then turning east to the broad summit, which it crosses at an elevation of 5,190 feet. Five miles west of the summit, at an elevation of 3,700 feet, the trail follows Coal or Summit creek, which here cuts through a thick series of shales, sandstones and conglomerates on which the Davis claims are located.

These sedimentaries have been upturned to high angles, in some cases standing vertical, and their strike is somewhat east of north. Summit creek flowing west has worn through the beds a canyon with precipitous walls from one to three hundred feet high, in which a cross-section of the bedding is well shown for several thousand feet. Scattered through the series are a number of so-called "veins" of coal and carbonaceous shale, varying in thickness from two to twenty feet. Most of these veins are conformable with the under and overlying layers of sediment, and are distinguished by their dark color, which is due to the carbonaceous matter present. The shale within the veins is finely bedded and contains some bone. Considerable crushing and slipping has occurred in certain places, forming slickensides and false walls, and mak-

ing a resulting mass of soft, loose coal and shale. Faults and folds are small and of rare occurrence, so far as the present surface shows. The "veins" of black shale and coal appear to maintain their proper widths and positions in the series, but observations on this point can hardly be made with exactness.

The streams north and south of Summit creek at the Davis claims run in a general westerly direction parallel to them. The strike of the coal-bearing shales may be traced nearly to the top of the ridge south of Summit creek, where the edges of the upturned beds are covered by a lava sheet, and the shales outcrop in several streams to the south. About two miles

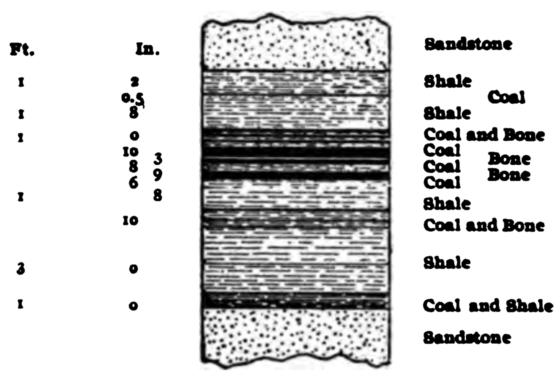


Fig. 43. Cross-section of Coal Measures on Summit Creek, Davis Field. Dip 11° N. 22° E.

north of the Davis claims, on the ridge which forms the divide between Summit and Carlton creeks, several coal prospects have been opened. Tunnels have been driven near the top of the ridge, on the Carlton slope, and also on the north side of Carlton creek. The occurrence of the coal is quite similar to that on Summit creek and the direction of the beds would indicate that they are identical or else nearly in the same geological horizon. Other claims have been located near Fish lake, three or four miles to the northeast of Carlton creek. One of the seams already exposed shows fourteen inches of clean, solid coal, while others show as much as eight or ten inches.

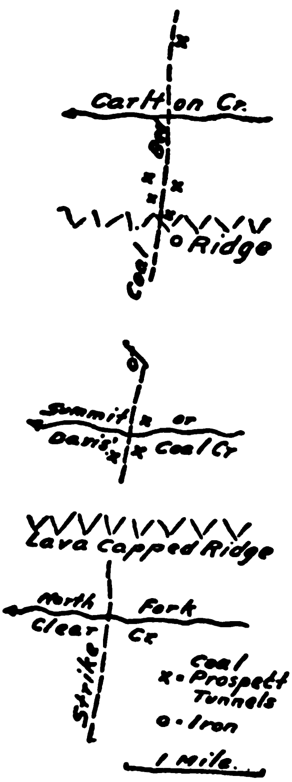


Fig. 44. Map showing Coal Prospects in Davis Field.

The following section appears on the north bank of Summit creek, below the Davis claims. Dip of beds nearly vertical. Downstream, for east to west. Distances by pacing:

	Feet.
Carbonaceous shale with very thin streaks of coal.....	5
Fine laminated sandstone and shale	20
Coal-bearing black shale	16
Soft and hard gray shale	35
Carbonaceous shale (one seam of clean coal 6 inches, one 3 inches, several ½ to 2 inches thick)............	12
Shale and sandstone	20
Carbonaceous shale, with clean coal in streaks from ¼ to 3 inches thick	3

Shale and sandstone, with 6 "veins" of carbonaceous shale from 3 to 12 feet thick, each containing thin streaks of clean coal	300
Carbonaceous shale with coal	25
Sandstone	60
Carbonaceous shale	12-20

COWLITZ COUNTY.

Kelso-Castle Rock Field.

The coal of the Kelso-Castle Rock field is not of very great commercial importance at the present time. There is a large extent of territory on both sides of the lower Cowlitz river that is underlaid with coal. At a large number of places prospecting has been done, but in no case thus far has a large body of first class coal been found. The coal is a low grade lignite, quite high in moisture and in ash. The quality of the coal in the different prospects is variable, being much better in some places than in others. The country is for the most part very heavily timbered and the hills are worn into low, rounded forms, so that the solid rock does not show in many places. The soft coal-bearing rocks have been much decomposed and a residual soil many feet in thickness has been formed. Because of the heavy mantle of soil it is not easy to state the exact boundaries of the coal-bearing territory. It is probable that as the district becomes better known the boundaries of the area of productive coal measures will be greatly extended.

Throughout its lower course the Cowlitz river flows through a flat, alluvial valley a mile or two in width, bordered by low hills, which gradually increase in height as they recede from the river. The tide flows up the river several miles above Kelso. At Rocky Point and at Castle Rock bold bluffs of hard, basaltic lava extend out into the valley. In the vicinity of Kelso and farther up the river there are remnants of a rocky bench or terrace about fifty feet above the level floor of the valley.

The coal-bearing rocks are shale and impure sandstone, probably of Eocene age. They have been upturned only to a

slight degree. Along the Cowlitz river the rocks may be seen in places dipping at low angles. The basalts are of later age than the sandstones and evidently are dikes which have broken through the older formation.

The Coal Creek Development Company of The Dalles, Oregon, is operating a small coal mine on Coal creek about eight miles west of Kelso. The coal is a lignite rather high in moisture, but suitable for domestic use. Portland is the market for this coal.

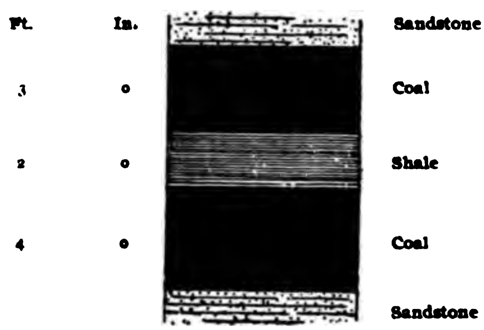


Fig. 45. Cross-section of vein, Coal Creek Development Co's Mine, near Kelso.

The Oregon Coal and Timber Company, of Portland, Oregon, has been endeavoring to open up the old Idleman mine, situated in sections 12 and 13, T. 9 N., R. 2 W., about a mile and a half east of Castle Rock. The mine was operated by Mr. C. M. Idleman a number of years ago. It was worked in a small way until 1893, when it was closed down on account of litigation. The present company began operations late in the fall of 1901. There are three veins having widths of four feet six inches, four feet one inch, and six feet, respectively. Still other veins of unknown thickness outcrop below these.

Another mine, known as the Red Ash, was opened up several years ago on Arkansas creek, about two or three miles west of Castle Rock. A considerable amount of coal was shipped to Portland and other places, where it is said to have given good satisfaction. The mine was closed down about three years ago and nothing has been done with it since. The

vein is said to have been several feet in thickness and to be composed of good, clean coal.

The Anchor mine is another old mine that was worked for awhile and then abandoned. It is situated in section 13, T. 8 N., R. 2 W., about three miles northeast of Kelso. Two veins were worked, one four feet and the other five feet in thickness. The mine was operated for several years prior to 1898, but has not been working since that time.

The Carbondale mine, three miles southeast of Castle Rock, in section 24, T. 9 N., R. 1 W., has been developed to some extent, but has not yet been put on a shipping basis. Other prospects have been opened in the N. W. ¼ of section 24, T. 10 N., R. 1 W.; in section 24, T. 9 N., R. 1 W., and in sections 8 and 18, T. 10 N., R. 1 E.

CHAPTER III.

THE COAL SEAMS.

NUMBER AND CHARACTER.

Carbonaceous matter occurs practically throughout the whole extent of the Eocene beds in Washington, either disseminated through the rocks or concentrated into coal veins. The shale owes its dark color to the fine particles of carbon which it contains and all gradations are found between shale and clean coal. The sandstones generally contain little streaks of coal. Much of the carbon of both the shale and sandstone is held in the form of iron carbonate.

Conditions favorable for the formation of coal beds occurred repeatedly throughout the long period during which the Eocene sediments were being laid down. In some fields over one hundred distinct coal seams have been observed. Of these, however, only a small proportion are clean enough and large enough to be of value, the number of workable veins in the different mines varying from one to seven or eight. Few veins are worked whose thickness of coal is less than three feet. It seldom or never happens that a vein is made entirely of clean coal; there are nearly always present one or more distinct layers of shale, sand, or impure coal varying in width from a fraction of an inch to several feet. Some of the largest veins attain a thickness of forty or fifty feet. In these veins only a small portion, if any, is workable coal and the remainder of the veins is made up of more or less impure coal, bone, shale, and clay occuring in distinct layers. From this it will be seen that the contents of a vein may vary rapidly in quality in a cross-section of the vein but longitudinally its contents will be quite uniform over large areas; that is to say, each layer within the vein differs from those above and below it, but maintains its own characteristics of composition and structure for long distances. It

usually happens that one or more of the impure seams must be mined with the coal and this requires washing and hand picking. In the lignite mines where the danger of spontaneous combustion is great, all the coal contents of the vein whether pure or impure must be removed.

In addition to the impurities which occur in more or less well defined layers there is always a certain amount of dirt in the coal which cannot be removed by washing, because it is too intimately mixed with the coal itself. The ash which is contained in coal is derived from two sources. In the first place, there is the wood ash which was contained in the vegetal matter from which the coal was formed, and in the second place there is the sand and mud which was washed into the coal swamp at the time of the deposition of the vegetal matter. The latter constitutes by far the greater portion of ash in nearly all coal veins. In a very few cases, however, notably that of the Black Diamond vein, the percentage of ash is very little more than a calculation based on the amount of wood ash in the original plants would indicate. The ash in Washington coals varies from one per cent up to fifteen or eighteen, at which point the coal ceases to be of any commercial value.

It is the ash percentage which in nearly every case determines whether or not a coal can be marketed. There are few lignite veins in the state whose percentages of moisture and other volatile constituents are so high as to render them of no value commercially. A large amount of ash, besides being totally inert so far as heat producing is concerned, is a positive injury on account of its clinging to the grate bars of furnaces and requiring frequent cleaning of the fires.

VARIETIES OF COAL.

The physical appearance of coal is to a considerable extent an index to its composition and to the conditions under which it has existed. The lignite occurs in rocks which have undergone only a moderate amount of tilting without any shearing movement having taken place within the coal beds and their hard consolidated condition is due to the

superincumbent weight of sediments. The soft coking coals indicate a much greater degree of folding and shearing. The walls of the coal veins have been rolled one upon another until the coal has been ground into powder. Nearly all the moisture has been expelled and the percentage of volatile combustible material greatly reduced, with a conseqeunt increase in the percentage of fixed carbon.

Few coals have been found in the state whose percentage of carbon both fixed and volatile is over ninety per cent. and which, therefore, could properly be classed as anthracite. In certain limited areas in Lewis county and elsewhere in the near neighborhood of igneous masses the coal has been reduced to anthracite. The coal in this condition is steel-gray in appearance and is quite hard and compact. It ignites with great difficulty. No large amount of it has ever been taken out so that no satisfactory boiler tests have been made.

There are certain characteristics which mark the coal of the different fields. These are due in part to the different conditions under which the coal was originally formed and in part to the subsequent history of the field. The coals of the state fall naturally into three classes, viz., lignite, semi-bituminous, or steam coals and bituminous coking coals. A fourth class might be added, that of anthracite, but up to the present time the anthracite fields have not been developed and little is known as to their commercial value. The dividing line between the different classes is to a certain extent indeterminate, but as a rule the different kinds of coal are confined within well marked geographical boundaries. Each field produces a certain quality of coal which is fairly uniform within the limits of that province. The classification is based upon the relative percentages of fixed carbon, volatile hydrocarbon, and moisture. The volatile constituents are highest in the lignite and lowest in the anthracite.

The Renton-Cedar mountain and Newcastle-Gilman fields are the most important lignite fields and the only ones which are producing on an extensive scale. The coal of Cowlitz and Thurston counties and western Lewis county is lignite and of an inferior quality as far as it has been opened up. Lignite

has a representative analysis of moisture 8 to 12 per cent., volatile hydrocarbons 35 to 45 per cent., fixed carbon 30 to 45 per cent., and varying amounts of ash. The coal is hard and breaks with a cubical fracture.

The semi-bituminous steam coals have a representative analysis of moisture 3 to 5 per cent, volatile hydrocarbon 30 to 40 per cent, and fixed carbon 40 to 50 per cent. This coal is best represented in the Green River field of King county. Chemically it is only one step removed from lignite, which it resembles in many respects. It has a higher heating capacity and is an excellent coal for locomotive and steamboat use. It is a free-burning coal and does not coke in the furnace. Nearly all of it is used for steam-making.

The bituminous coking-coal of the Wilkeson-Carbonado and Cokedale fields is still another step removed from lignite. A representative analysis of this coal is as follows: Moisture 1 to 3 per cent, volatile hydrocarbons 25 to 35 per cent, fixed carbon 50 to 60 per cent. Frequently the percentage of fixed carbon is considerably higher than this, especially in the Fairfax district and some of the coal might properly be classed as semi-anthracite. Most of the coking veins are greatly crushed and their contents have undergone considerable chemical change. The coal comes from the mine mostly in the form of fine slack. Where it is destined to be made into coke no attempt is made to mine the coal in large sizes, but where the coal is intended for the market care is taken not to break it finer than necessary. It is a good steam and domestic coal and a large amount of it is used for steamboats and locomotives. It cakes to a certain extent in the furnace and requires frequent working but it makes an intense heat. Most of this coal carries a considerable percentage of ash, usually more than the other coals. This is due largely to the fact that a certain amount of the wall rock has been mixed with the coal during the process of rolling to which the veins have been subjected. The dirt partings in the veins have in many cases become obliterated and so intimately mixed with the coal that it is impossibie to wash it thoroughly.

The Roslyn coal belongs to the bituminous coking group but unlike the others it is very hard, and shows no tendency to crumble. A very large percentage of it reaches the market as lump coal. A 25-ton block of Roslyn coal was exhibited at the Chicago World's Fair. The Roslyn coal has not been subjected to the same degree of close folding as the other bituminous coals of the state, and very little mechanical change has taken place within the veins since they were formed.

Normally the Roslyn coal with its gentle folds would not have passed beyond the lignite stage were it not for some other cause which has hastened the process of distillation. This cause may be sought in the great sheets of basaltic lava which are known to underlie the Roslyn formation. They outflowed only a short time prior to the deposition of the Roslyn sediments and the buried sediments in comparatively close contact with the heated lavas undoubtedly reached a higher temperature than coal veins under normal conditions. It is well known that destructive distillation of the volatile elements of coal will take place at a comparatively low temperature, and the higher the temperature the more rapidly will distillation proceed. The conditions under which the Roslyn coal was originally formed probably differ considerably from those obtained in the Puget Sound region, and distillation of the volatile hydrocarbons may have reached an advanced stage before the carbonaceous matter forming the veins was finally buried by the succeeding sediments.

Anthracite has been formed only in the vicinity of dikes or masses of eruptive rocks. The intense heating of the coal where it has come in contact with the molten mass of intrusive rock has in several instances caused nearly all the volatile matter to be dissipated and only the ash and fixed carbon remain. The anthracite areas occur usually high in the mountains where the volcanic action has been severe. The coal measures have been broken across by numerous dikes, and sheets of lava have been forced in between the beds for long distances.

It is possible for coal to pass through all the stages from

lignite to anthracite without undergoing any great disturbance of the strata, providing the superincumbent mass of rock is sufficiently great and the time during which the pressure has been acting is long enough. The bituminous coal veins of the states of the middle west still remain nearly all in their original horizontal position. They are of Carboniferous age and the very long period during which they have been subjected to the pressure of the rocks lying upon them has gradually driven off the volatile matter to such an extent as to render the coal bituminous. The coal of Washington is very much younger and normally would still be in the lignite stage, but some of it has taken what may be called a short cut to the bituminous class. This result has been brought about by a sharp folding of the rocks and the intrusion of dikes into the strata. Thus the same result has been arrived at in a fraction of the time required for the eastern bituminous coal fields but it has been accomplished only at the cost of destroying to a large extent the regularity of the strata. It has improved the quality of the coal so far as an increase in the percentage of fixed carbon is concerned, but it has usually increased the percentage of ash and in a number of cases rendered the veins so dirty as to destroy entirely their commercial value.

The introduction of washeries in recent years has served greatly to increase the supply of marketable coal. Only the finer coal is washed but in most of the mines this forms a large percentage of the whole. All of the larger mines except Roslyn and Black Diamond have washeries in operation whose capacity is from three hundred to fifteen hundred tons per day.

COMPOSITION AND HEATING POWER OF THE COAL.

The volatile combustible constituents of coal are composed of members of the hydrocarbon group of compounds. They differ from the so-called fixed carbon by reason of the greater ease with which they volatilize under moderate heat. When coal high in volatile matter is thrown into the furnace great volumes of dense black or brown smoke immediately pour

forth. This is an indication of imperfect combustion and consequently great loss of heat-producing power. The dark color of the smoke is due to finely disseminated particles of carbon of which it is composed. The ordinary type of furnace does not give sufficient ventilation to oxidize the volatile hydrocarbon and it requires some type of so-called smoke consumer to utilize all the heat producing qualities of these coals. The great value of anthracite lies in the fact that it contains only a small percentage of volatile constituents and practically all its heating qualities can be utilized.

The exact chemical combination in which the various elements in the coal are held together is not definitely known so that when we speak of fixed carbon the term must be understood only in a relative sense. The percentage of fixed carbon is lowest in lignite and highest in anthracite and the heating power of the different varieties of coal is in a general way in direct ratio to the amount of fixed carbon.

None of the Washington coal carries a very high percentage of sulphur and in most of it the amount is very low. While sulphur oxidizes under heat and produces considerable heat a certain amount of it reacts with the other constituents of the coal to form sulphuric acid which attacks the iron of the grate bars and boiler tubes. Where coal is used for coke making the presence of sulphur detracts from the value of the coke, especially for foundry use. Nearly all of the coke made in the state is for foundry and smelter use. In that which is used in smelters the amount of sulphur in the coke is of no consequence but for foundry use if the coke contain more than a very small percentage of sulphur the iron is injured thereby.

The moisture in Washington coal varies from less than one per cent up to nearly twenty per cent. It is smallest in the soft bituminous coking coals and greatest in the brown lignites of Lewis and Cowlitz counties. The moisture is not only entirely inert as far as heat producing is concerned but works a positive injury, because a considerable amount of heat is consumed in vaporizing the moisture before any of it is available for heating outside objects. For this reason

a coal high in moisture makes a very inferior steam coal and finds its greatest use in domestic purposes where the heat requirements are not so great.

So closely is the chemical composition of the coal related to the structure of the field that a chemical analysis is a good index to the amount of movement which the strata have suffered. The greater the degree of disturbance the greater the percentage of fixed carbon and the smaller the percentage of volatile constituents.

The Bureau of Naval Equipment at Washington, D. C., has made a large number of tests on different coals including some from this state. The Bureau undertakes to furnish a free analysis to any one who will forward a sample of at least four pounds weight. Evaporative tests are made at the New York and Mare Island Navy yards for any one who will furnish free of charge a lot of twelve tons.

The following table shows the result of the analyses made on some of the Washington coal:

Name	Moisture	Phosphorus	Volatile matter	Fixed Carbon	Ash	Sulphur
Blue Canyon	1.790	.006	31.479	62.744	3.679	.308
Fairhaven	2.980	....	35.030	59.980	2.010	.202
Wilkeson	.700	.009	23.545	56.895	18.715	.145
Franklin (McKay Vein)	1.300	.007	39.254	56.400	2.884	.162
Roslyn	1 450	.008	32.794	53.656	11.944	.156
Newcastle No. 4 Vein	13.590	....	32.310	48.320	5.780	.164
Black Diamond	3.040	.023	36.566	56.084	4.166	.144
Fairhaven	.310	.245	22.265	62.395	14.885	.145
Gilman	10.240	.004	32.640	51.321	5.714	.085
Franklin	3.260	....	35.360	57.580	3.800	.097
Roslyn	2.050	....	33.550	54.550	6.850	.106
Roslyn	2.718	....	34.275	50.109	12.753	.145
Franklin	4.559	....	33.501	46.668	15.080	.192

"The amount of moisture shown in the first column indicates to some extent the liability of the coal to spontaneous combustion since the presence of moisture is necessary to the generation of heat."

"The amount of fixed carbon indicates heat-giving properties. The amount of combustible volatile matter is of value

in determining the rapidity of combustion. A coal rich in combustible gases usually burns rapidly."

The following boiler tests made on the U. S. S. Yorktown indicate the comparative heating power of some of the Washington coals:

NAME OF COAL	Coal burned per hour	Burned per H. P. per hour	Refuse	Knots per ton of coal	H. P.
	Pounds	Pounds	Percentage		
Comox B. C.	2,288	2.70	34	11.3	845
Black Diamond	2,478	3.51	14	9.6	706
Black Diamond	2,164	4.45	14	9.4	486
Fairhaven	2,575	3.40	20	9.4	756
Blue Canyon	2,599	2.53	16	10.2	1025
Blue Canyon	2,336	2.50	27	9.3	934

The following tests of coal from various mines made at the Mare Island Navy yard will serve as a basis of comparison between the Washington coals and those from other sources:

NAME OF COAL	Coal consumed per hour per sq. ft. of grate surface	Water evaporated per pound of coal	Equivalent evaporations from and at 212° per lb. of coal	Refuse
	Pounds	Pounds	Pounds	Per cent.
Albion Cardiff (Wales)	10.00	9.07	10.69	10.00
Comox B. C.	12.77	7.689	9.027	14.70
Wellington B. C.	13.48	7.146	8.389	11.87
Castle Gate (Utah)	12.296	6.934	8.123	12.049
Franklin	14.33	6.78	7.94	13.33
Nanaimo B. C.	14.35	6.5077	7.6315	15.45
Roslyn	14.24	6.243	7.315	16.20
Newcastle	15.14	5.965	6.996	10.50
Fairhaven	11.178	6.853	8.05	19.95
Roslyn	13.387	6.827	7.09	11.66

Steaming tests have been made by vessels of the United States navy on the coal from a number of Washington mines with results as follows: On the U. S. S. Mohican the following coals were tested:

Coal from Franklin (McKay vein) was tested and found to be free burning coal, the fires requiring very little working, firing lightly every twelve or fifteen minutes. The fires

required cleaning once in eight hours. There is a very little clinker of a brittle character and does not adhere to the grate bars. When fresh coal is thrown on the fires there is a dense smoke of a grayish black color. The tubes did not require sweeping during the run in either the low speed or the high speed tests. There was very little soot to sweep out at the end of the test.

Roslyn. The coal from the Roslyn mine received aboard the Mohican at Tacoma was found to be a free burning coal; the fires required little working, firing lightly about every fifteen minutes. The fires required cleaning once in eight hours. Only a small quantity of clinker was found, which was easily broken, and did not adhere to the grate-bars. There is a considerable volume of grayish colored smoke when fresh coal is thrown on the fire. Tests were made at low and high speed under natural draft. Sweeping of the tubes was not found necessary after either of the tests. The ashes are of a reddish color.

Wilkeson. The coal from this mine was in the form of very small lump and slack. It ignites quickly. There is a little gray smoke at first which ceases as the coal cakes so there is hardly any smoke when the fires are not being worked. The coal cakes in the furnace and requires considerable working of the fires. While it ignites readily it requires a strong draft. Under a high speed test the coal worked well for three hours, when it became necessary to clean the grates. The tubes did not require cleaning during either of the trial trips.

Blue Canyon. This is a free-burning coal requiring very little work at the fires. There is no clinker and the fires did not require cleaning during either of the trial tests. It is a good steaming coal and cakes very little in the furnace. There is considerable smoke of a grayish black color when the coal is first thrown in the furnace, thinning out after the coal is thoroughly ignited. The consignment used in these tests was nearly all small lump coal with only a small percentage of slack.

Fairhaven. (Cokedale). This coal gave a high percentage of ash of a light cream color. In the furnace the coal caked and coked very readily and required a great deal of working. After a trial of four hours a large amount of hard brittle clinkers remained, which however did not adhere to the grates and were easily removed. During the low speed tests no difficulty was found in maintaining sufficient steam pressure but in the high speed tests steam could not be made fast enough to fulfil the requirements. The smoke is light gray in color, and thins out when not firing until it is almost invisible.

Navy Mine. This coal is very inflammable and burns freely, leaving a small quantity of cream colored ash. It does not coke or cake and makes only a small quantity of clinkers which do not adhere to the grate bars. The best results were obtained by firing lightly at short intervals. In the thirty revolution test it was frequently necessary to check the draft in order to reduce the steam pressure. In the forty revolution test the fires were clinkered, and in the fifty revolution test the fires were kept in good condition only by running the bar through the fires to shake them clear of ashes to admit air for combustion. It was not necessary to sweep the tubes during the tests. The smoke was of a dark gray color when first firing, thinning out in volume and becoming lighter in color when combustion was going on. During the intervals that the fires were not worked no smoke at all was visible.

Black Diamond. Scarcely any injurious results were observed from the use of this coal. It showed a remarkably low percentage of ash, and did not cake or coke in the furnace. This coal ignites immediately upon being fired and is consumed with great rapidity, giving forth an intense heat but soon burning out. The coal made no body in the fire and on this account considerable care was necessary in cleaning and shaking fires. It was rapidly broken into small fragments as soon as brought into contact with the fires and some loss was incurred from the dropping of unburnt fuel through the grate bars. A light thin clinker was formed which did not

adhere to the grate bars and was easily removed, but in any long distance steaming the removal of the clinker would practically mean the removal of almost all the fire in the furnace. Steam was maintained with ease at the thirty revolution test, in fact it became necessary frequently to retard the combustion. At forty revolutions the coal burned up rapidly in keeping up the required steam pressure. At fifty revolutions with six boilers difficulty was experienced in keeping the steam pressure to the required point as the coal burned up almost as fast as it was fired. At thirty revolutions no cleaning of the grates was necessary; at forty revolutions the fires were cleaned of clinkers after eight hours, and at fifty revolutions it was necessary to clinker the fires after three hours. The smoke was of a grayish brown color rather dense at first and rapidly thinning out during combustion.

TABLE OF COAL ANALYSES.

LOCALITY	Water	Volatile matter	Fixed carbon	Sulphur	Ash	Analyst or authority
WHATCOM COUNTY—						
Blue Canyon	2.73	36.59	57.71	.76	2.21	1.
Blue Canyon	1.79	31.48	62.74	.308	3.68	3.
Cornell Creek	0.37	17.10	78.27	.74	3.52	1.
Cornell Creek, T. 39, N. R. 3. E	0.13	4.89	92.48	....	2.50	6.
SKAGIT COUNTY—						
Hamilton	1.19	18.80	71.66	....	8.35	4.
Cokedale	.53	26.67	64.51	.68	8.29	2.
KING COUNTY—						
Newcastle, No. 4 Vein	6.64	36.91	53.80	....	2.65	4.
Newcastle, No. 2 Vein	2.12	46.57	43.90	.13	7.28	4.
Newcastle, Bagley Vein	7.22	42.36	44.86	....	5.56	4.
Gilman, No. 2 Vein	4.80	47.04	37.19	....	10.06	4.
Gilman, No. 4 vein	2.05	32.64	53.49	....	11.40	4.
Gilman, No. 6 Vein	12.36	31.91	52.65	....	3.08	4.
Renton, No. 2 Vein	3.44	37.38	53.60	.73	5.58	2.
Cedar Mountain	13.00	41.40	37.20	....	8.40	4.
Snoqualmie	3.92	14.99	79.66	.33	1.10	3.
Black Diamond	3.04	36.56	56.08	.144	4.16	3.
Franklin, No. 10 Vein	3.33	33.92	57.68	....	5.07	4.
Franklin, No. 12 Vein	3.66	34.63	50.78	....	10.93	4.
Franklin, No. 14 or McKay	1.30	39.25	56.40	.162	2.88	3.
Kangley	1.00	45.50	52.00	....	1.50	4.
PIERCE COUNTY—						
Burnett	2.59	34.49	59.89	....	3.03	4.
Wilkeson	1.87	25.56	62.87	....	9.70	4.
Wilkeson (coke)	.20	1.82	80.57	.66	16.75	1.
Carbonado, Miller Vein	1.69	41.00	48.95	....	8.35	5.
Carbonado, Wingate Vein	1.80	42.27	52.11	....	3.82	5.
Carbonado, Average nine veins	1.74	30.70	58.30	....	9.26	4.
Melmont, No. 3 vein	1.03	21.15	66.55	.46	10.81	1.
Fairfax, No. 5 vein	.51	23.46	70.72	.62	4.69	1.
Fairfax (coke)	.00	.55	81.79	.54	17.12	1.
Montezuma, Blacksmith vein	.49	25.97	70.11	.60	2.83	1.
Hillsboro, No. 6 vein	1.00	11.98	79.01	.54	7.47	1.
KITTITAS COUNTY—						
Roslyn	2.05	33.55	54.55	.106	6.85	3.
Roslyn	3.35	30.29	59.31	.12	6.93	4.
THURSTON COUNTY—						
Bucoda	2.55	35.40	49.75	....	12.30	4.
Tenino, Great Western Mine	15.59	33.73	46.64	1.18	2.86	1.
LEWIS COUNTY—						
Chehalis, Rosenthal Mine	15.46	40.86	35.48	2.06	6.14	1.
Centralia, Salzer Valley Mine	20.04	38.83	33.32	1.90	5.91	1.
Claquato, Crescent Mine	19.79	42.02	34.27	0.34	3.58	1.
Cinebar, Big Betsy Vein	1.78	28.85	65.40	0.54	3.43	1.
Morton, S. 6 T. 12 N. R. 5 E	1.57	7.87	84.82	1.70	4.04	1.
Morton, S. 30 T. 13 N. R. 5 E	1.80	34.27	58.93	1.34	3.66	1.
Morton, S. 24 T. 13 N. R. 4 E	3.71	35.03	59.01	1.24	1.01	1.
Verndale, S. 20 T. 13 N. R. 6 E	2.67	4.86	88.66	1.22	2.59	1.
Cowlitz Pass, Davis Mine	1.09	6.79	86.18	.74	5.20	1.
COWLITZ COUNTY—						
Coal Creek	9.57	43.93	41.84	0.72	3.94	1.

ANALYST OR AUTHORITY.

1. **Paul Hopkins, University of Washington.**
2. **Edward H. Young. Washington Agricultural College and School of Science.**
3. **United States Navy Yard, Washington, D. C.**
4. **Second Annual Report, Coal Mine Inspector of Washington.**
5. **Volume 15, Tenth Census.**
6. **Thomas Price and Son, San Francisco.**

CHAPTER IV.

EXTENT OF COAL INDUSTRY.

PRODUCTION OF COAL AND COKE.

The total output of the various mines of the state for the year 1902, as given by the State Mine Inspector, Mr. C. F. Owen, is given in the table below. In this table the output of a few mines where only a small number of men are employed is not given. The combined product of these mines amounts to only a few hundred tons per year.

NAME OF COMPANY	LOCATION OF MINE	Output of Coal (short tons)	Output of Coke (short tons)
Northwestern Imp. Co.	Roslyn	1,039,870	....
Black Diamond Coal Mining Co.	Black Diamond	258,996	....
Northwestern Imp. Co.	Clealum	212,584	....
Carbon Hill Coal Co.	Carbonado	169,733	....
Pacific Coast Co.	Newcastle	140,841	....
Issaquah Coal Co.	Issaquah	117,184	....
Pacific Coast Co.	Lawson	107,750	....
Wilkeson Coal and Coke Co.	Wilkeson	106,896	22,800
Seattle Electric Co.	Renton	104,071	....
Pacific Coast Co.	Franklin No. 7	72,238	....
The S. & S. Ry. & Nav. Co.	Ravensdale	71,426	....
Pacific Coast Co.	Franklin No. 1	65,107	....
Pacific Coast Co.	Franklin Gem	52.735	....
Western American Co.	Fairfax	32,117	17,168
South Prairie Coal Co.	Burnett	32,003	....
Gale Creek Coal Co.	Wilkeson	29,640	....
Northwestern Imp. Co.	Melmont	24,000	....
Skagit Coal & Coke Co.	Cokedale	19,017	601
Denny Clay Co.	Kummer	10,044	....
Fred Nolte Co.	Cumberland	8,600	....
Wash. Co-op. Mining Co.	Montezuma	6,702	....
Blue Canyon Coal Co.	Blue Canyon	6.010	....
P. Gibbons	Palmer	3.225	....
Totals		2,690,789	40,569

COAL OUTPUT BY COUNTIES, 1902.

Kittitas	1,252,454
King	1,012,217
Pierce	401,091
Skagit	19,017
Whatcom	6,010

STATISTICS CONCERNING COKE PRODUCTION SINCE 1884.

Years	Establishments	Number of Ovens in operation	Coal used (short tons)	Coke produced (short tons)	Total value of coke at ovens	Value of coke at ovens per ton	Yield of coal in coke per cent.
1884	1	0	700	400	$ 1,900	$ 4.75	57.5
1885	1	2	544	311	1,477	4.75	57
1886	1	11	1,400	825	4,125	5.00	58.9
1887	1	30	22,500	14,625	102,375	7.00	65
1888	3	30	....	....	....	....	....
1889	1	30	6,983	3,841	30,728	8.00	55
1890	2	30	9,120	5,837	46,696	8.00	64
1891	2	80	10,000	6,000	42,000	7.00	60
1892	3	84	12,372	7,177	50,446	7.03	58
1893	3	84	11,374	6,731	34,207	5.08	59
1894	3	84	8,563	5,245	18,249	3.48	61.2
1895	3	110	22,973	15,129	64,632	4.27	65.9
1896	3	120	38,685	25,949	104,894	4.04	67
1897	3	120	39,124	26,189	115,754	4.42	67
1898	2	90	48,559	30,197	128,933	4.27	62.2
1899	2	90	50,813	30,372	151,216	4.98	59.8
1900	3	90	57,756	35,921	178,012	4.90	65
1901	3	150	....	49,197	245,985	5.00	....
1902	3	....	....	40,569	202,845	5.00	....

STATISTICS CONCERNING COAL PRODUCTION SINCE 1870.

YEAR	Total Product (short tons)	Total Value	Average price per ton at the mine	Average number of days active	Total number of employes
1870	17,844	$	$		
1871	20,000				
1872	23,000				
1873	26,000				
1874	30,352				
1875	99,568				
1876	110,342				
1877	120,896				
1878	131,660				
1879	142,666				
1880	144,315	389,046	2.70		168
1881	167,554				
1882	177,340				
1883	244,990				
1884	166,936				
1885	380,250				
1886	423,525	952,931	2.25		
1887	772,601	1,699,746	2.19		1571
1888	1,215,750	3,647,250	3.00		
1889	1,030,578	2,393,238	2.32		2657
1890	1,263,689	3,426,590	2.71	270	2006
1891	1,056,249	2,437,270	2.31	211	2447
1892	1,213,427	2,763,547	2.28	247	2564
1893	1,264,877	2,920,876	2.31	241	2757
1894	1,106,470	2,578,441	2.33	207	2662
1895	1,191,410	2,577,958	2.16	224	2840
1896	1,195,504	2,396,078	2.00	221	2622
1897	1,434,112	2,777,687	1.94	236	2739
1898	1,884,571	3,352,798	1.78	270	3145
1899	2,029,881	3,603,989	1.78	259	3330
1902	2,418,034	4,425,002	1.83	260	4338
1901	2,466,190	4,586,327	1.83	273	4826
1902	2,690,789	5,300,854	1.97	266	4342

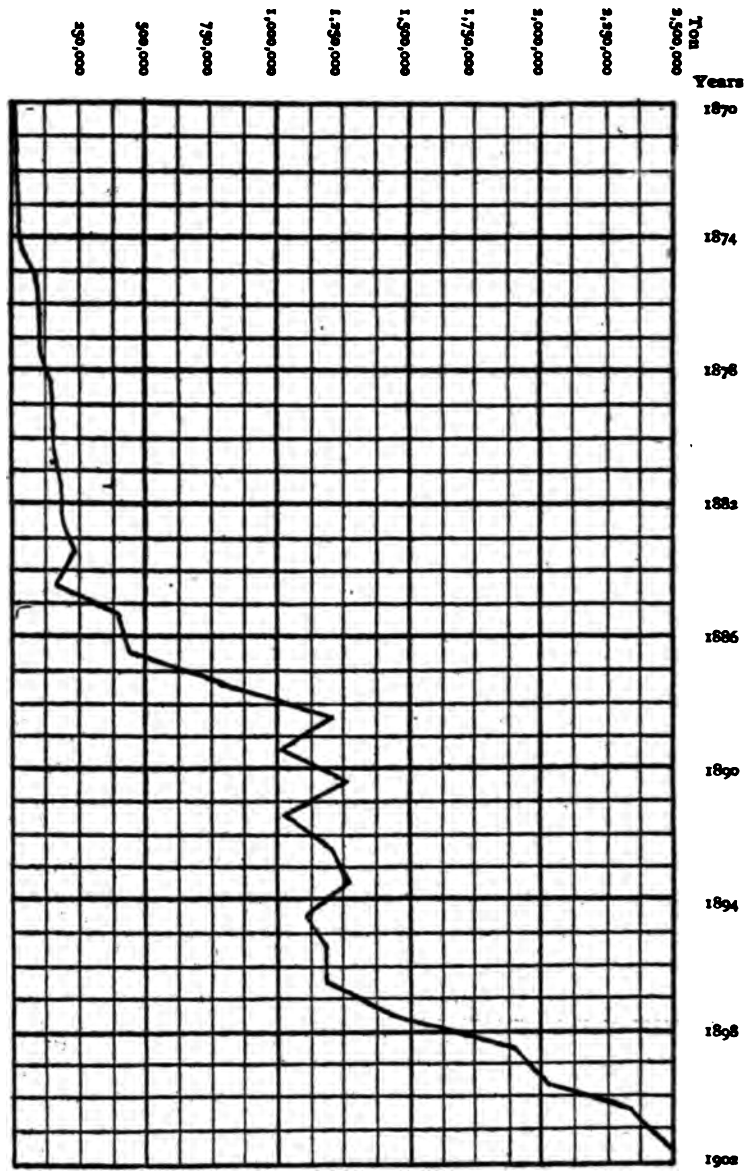


Fig. 46. Production of Washington Coal Mines from 1870 to 1902.

MARKETS.

San Francisco has always been the most important market for Washington coal outside of the state. The first regular shipments to San Francisco were made from the old Bellingham Bay mine in Whatcom county. In the year 1860 the shipments amounted to 5,490 tons. For the years 1869, 1871, 1873, and 1876 the San Francisco shipments exceeded 20,000 tons. The total amount for the nineteen years in which the mine was in operation was 233,043 tons.

Shipments from Seattle to San Francisco began in 1871 when 4,918 tons were shipped. In 1880 the shipments increased to 123,741 tons, in 1890 to 216,760 tons, and in 1899 to 349,813 tons. The mines tributary to Seattle and whose outputs are included in these figures are those of Renton, Newcastle, Issaquah, Cedar Mountain, Black Diamond, and Franklin. A considerable amount of Roslyn coal is also included.

The mines of the Carbonado-Wilkeson field are tributary to Tacoma and ship their product from that port. Shipments of coal from Tacoma to San Francisco began in 1879 in which year a few hundred tons were shipped. By 1890 the shipments had increased to 191,109 tons and in 1899 to 355,756 tons.

The coal receipts and shipments at Seattle for the years 1896-1901, inclusive, are shown by the following figures collected by Mr. Lovett M. Wood of the Seattle Trade Register:

Year.	Receipts (Short Tons.)	Shipments (Short Tons.)
1896	425,103	194,771
1897	472,311	287,883
1898	662,342	376,342
1899	806,029	435,624
1900	909,322	478,562
1901	991,788	482,679

According to the above table the increase of coal receipts from year to year is much greater than the increase of shipments. Thus the increase in receipts for 1901 over 1900 was 82,466 tons as against an increase in shipments of 4,117 tons. The difference between the increase in receipts and the increase in shipments is due to the growth in population and

rapid development of manufactures in Seattle. In the year 1900 Seattle consumed 430,760 tons and in 1901, 509,109 tons, an increase in consumption in one year of 78,349 tons.

The receipts at Tacoma for 1901 were 680,980 short tons, made up of shipments from Roslyn and the various mines of Pierce county. The total output of the Carbonado mine has heretofore been shipped to San Francisco by way of Tacoma for the use of the Southern Pacific Railway, but since the partial substitution of oil for fuel in their locomotives these shipments have fallen off, and much of the coal from this mine is being distributed among the various Sound cities for local consumption.

The great bulk of all the coal shipped from Seattle and Tacoma goes to San Francisco, but during the year 1901 a number of cargoes were sent to Hawaii as well as to Alaskan ports. Washington's chief competitor in the Alaskan coal trade is British Columbia. It is not unlikely that before many years, with theopening of her well known coal deposits, Alaska herself will become an exporter of coal and will enter into competition with the Washington mines for the export trade.

Most of the coal output is consumed within the borders of the state and as time goes on and the population of the state increases the proportion of coal consumed will be greater and greater. The largest single use to which coal is put is in the making of steam in locomotives, steam boats, and stationary boilers. Wood is used to a very large extent as a fuel in western Washington, but as the most accessible timber is being gradually exhausted we may expect to see a gradual substitution of coal for wood, especially in the larger towns and cities.

In the timberless region of eastern Washington, coal is very largely used for all purposes, even in the rural districts. Roslyn coal supplies nearly all of this part of the state. Along the lines of the O. R. and N. Company Roslyn coal is brought into competition with that from Rock Springs, Wyoming, and in the north eastern part of the state with British Columbia and Montana coal. In the city of Spokane 80 per cent of the coal used is from Roslyn.

The following table* shows the disposition of the coal output for 1900. It does not include the amount used at the mines for steam purposes.

Disposition of the coal output of Washington in 1900:

	Tons of 2,000 lbs.
Consumed by railroads in Washington, Idaho, Oregon, and Montana	611,728
Exported to California	783,481
Exported to Hawaiian Islands	70,894
Exported to Alaska	13,436
Consumed by steamers in foreign trade (plying between Puget Sound ports and the Orient)	43,452
Consumed by steamers in domestic trade	218,114
Consumed by United States vessels (naval vessels, revenue cutters and army transports)	42,715
Manufactured into coke	57,010
Consumed in Washington, Idaho and Oregon for domestic and steam purposes	577,204
Total output	2,418,034

* 22nd Annual Report U. S. Geological Survey Part III., p. 496. Pacific Coast Coal Fields. George Otis Smith.